Nasa CR

CBS LABORA

Contract No. NAS 9-4414

FINAL REPORT: DEVELOPMENT OF AN ELECTRONIC DUMMY FOR ACOUSTICAL TESTING (INCORPORATING MANUAL OF OPERATION AND DESIGN)

Prepared for

National Aeronautics and Space Administration
Manned Spacecraft Center
Houston, Texas

by

CBS LABORATORIES
Stamford, Connecticut
A Division of Columbia Broadcasting System, Inc.

March 28, 1966

TABLE OF CONTENTS

TABLE OF CONTENTS (cont.)

SECTION | PAGE

LIST OF ILLUSTRATIONS

FIGURE | PAGE

LIST OF ILLUSTRATIONS (cont.)

INTRODUCTION

The Electronic Dummy (ED) is a manikin which represents the average male torso from the Xiphoid process upward. Providing an exact replica of the human head, including the simulation of natural flesh impedances, the ED features an Artificial Voice which produces levels up to 100 db SPL at six inches, and a highly advanced Artificial Ear which measures sound pressures at the eardrum or the entrance to the ear canal. A unique hearing mode amplifier optionally provides automatic and continuously variable loudness contour equalization.

This program was conducted under NASA Contract No. NAS 9-4414, "Development of an Electronic Dummy (ED) for Acoustical Testing," by CBS Laboratories, Stamford, Connecticut, a Division of Columbia Broadcasting System, Inc. Sponsorship was by the National Aeronautics and Space Administration, Manned Spacecraft Center, Houston, Texas.

This report describes work started in June, 1965, and completed in February, 1966. Mr. Michael K. Hendrix, Government Project Engineer, was technical monitor for NASA. Key personnel for CBS Laboratories were Mr. Benjamin B. Bauer, Vice President, Acoustics and Magnetics, who directed the program, Emil L. Torick and Alfred L. DiMattia, Associate Branch Managers, technical supervisors for the electronics and and acoustical portions of the program, respectively, and Section Head Edward J. Foster and Project Engineers Louis A. Abbagnaro, Louis T. Fiore, and Allen J. Rosenheck, who contributed major participation to the program. The CBS Laboratories project number was 1037, and this report has been assigned the CBS number CLD-1760.

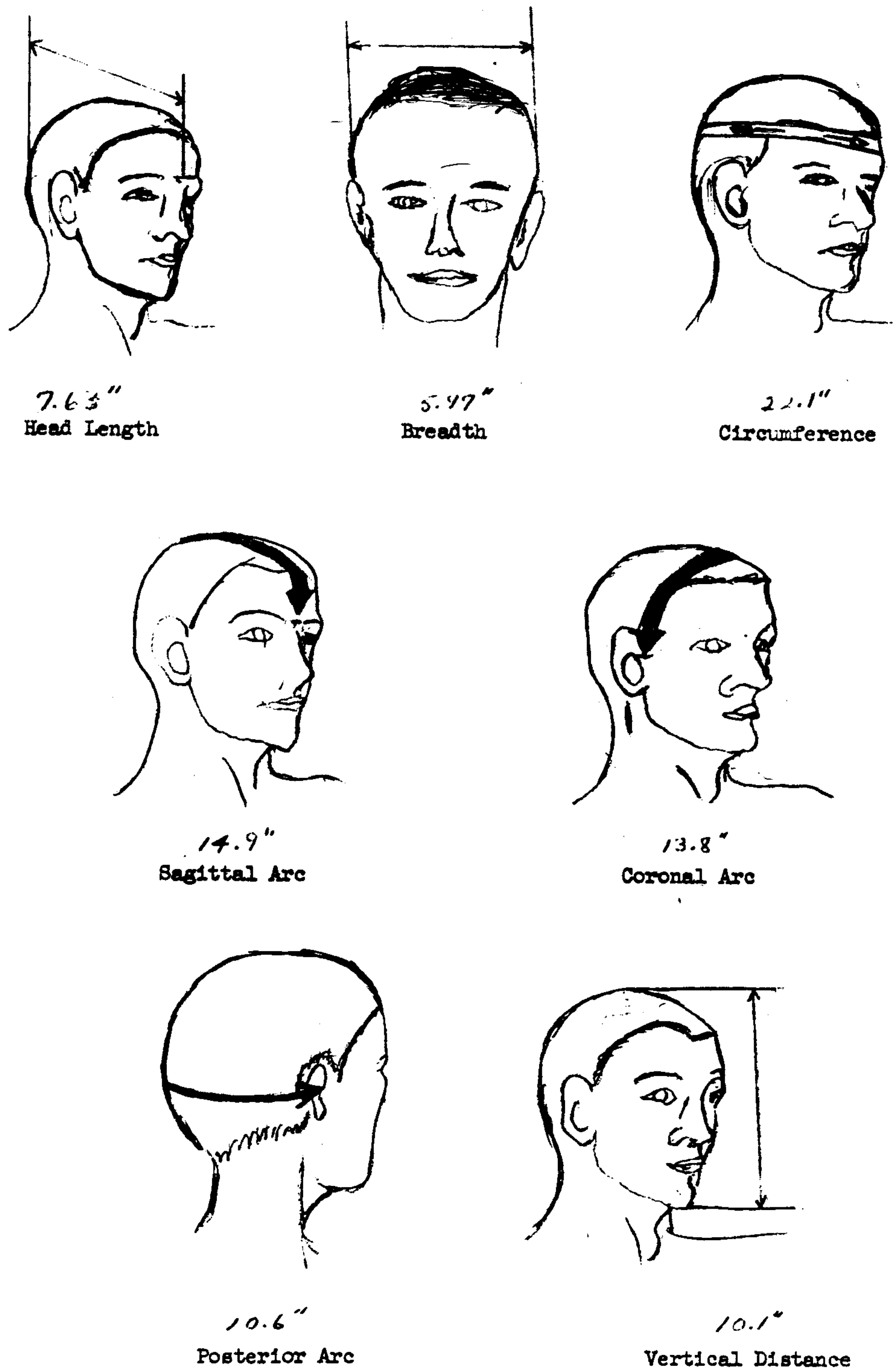


Figure 1. Dimensions of the Artificial Head

FABRICATION OF HEAD AND TORSO

General

The procedure that was followed in fabricating the head was governed by the following requirements set forth in the contract:

1. The head dimensions must conform to those supplied by NASA which are given in Figure 1.

2. The simulated flesh material must approximate the acoustical and mechanical properties of real flesh.

3. The head must be rugged enough to withstand the application and removal of tight fitting space helmets.

4. The simulated "skull" must be sufficiently rigid and strong to support required acoustical transducers within the head.

A search of materials indicated that the material which most closely simulated the acoustical and mechanical properties of flesh is a plastic formulation called "plastisol." This material is available in a variety of compliances, and is easily molded. Accordingly, it was selected for the simulated flesh material.

Careful consideration had to be given to the molding procedure to assure that the resulting head would conform to the dimensions given by NASA. Although simple slush molding techniques (i.e. forming the plastisol around a heated male mold) are expedient with plastisol, the exact build-up cannot be controlled, so that the dimensions would not be identical to those given by NASA. Accordingly, the plastisol had to be cast with an "outside-in" process using a female mold whose inside dimensions represent the proper outside dimensions required of the head.

The process of developing this female mold began with the sculpting of a clay model which conformed to the required dimensions. A local sculptor was employed for this purpose. Using this model, a series of subsequent male and female molds were generated, finally resulting in an electroformed female mold of nickel, having the identical inside dimensions of the original solid clay model.

Work then proceeded to cast the plastisol "flesh" within this mold. Originally, a flesh-colored plastisol having a durometer of approximately 8 to 10 was used. Initial castings indicated that this material was not sufficiently strong enough for the purposes of this program, and this necessitated replacing with a plastisol of somewhat higher durometer. Measurements indicated that the latter material had considerably higher tear strength, and it was therefore used for casting the final "flesh."

Since the head was required to support a vocal simulator and two aural simulators, a rigid "skull" had to be fabricated that fit beneath the plastisol flesh. Based upon the high stiffness-to-weight ratio of polyester-fiberglass and its adaptability to molding, this material was selected for the skull. A thickness of approximately 1/8" was found to be sufficiently rigid for the purpose.

The torso was supplied by a local manikin company to the needs of this program. It was fabricated of fiberglass, extending from the neck to the Xiphoid process.

AURAL SIMULATOR

A Review of Previous Research and Simulation Efforts

An investigation of past methods of aural simulation was made to determine whether any would be suitable for use in the ED. The most notable effort in this field was the development of the 6 cc coupler which is used for headphone calibrations. Originally, this coupler was designed to measure the response of telephone receivers (the 6 cc volume approximating the amount of air which is entrapped when the receiver is placed over the ear). Later this coupler was standardized as a method for measuring the transducers for all "over-the-ear" type receivers even though the actual volume in which these transducers was used was usually other than 6 cc. It is generally agreed that as a standard measuring tool, the 6 cc coupler serves only to compare the response of different headphones and does not give an absolute measurement of the response actual listeners would receive.[1,2,3] The limitations of this coupler as an exact aural simulator are given below:

1. As stated above, the 6 cc volume is not a true representation of the amount of air entrapped between the receiver and the ear in most situations, especially when the receiver is housed in a large circum-aural cup as is the case in military applications.

2. The coupler does not account for leaks which may occur when a phone is placed over the ear.

3. No acoustical resistance is present in the 6 cc coupler as it is in the ears, and thus, the phones are driving into a purely capacitive load.

4. There is poor correlation of coupler to real ear response at frequencies where ear canal resonances are prevalent. A report by two members of the National Bureau of Standards[2] indicated that good agreement between coupler and real listening response was obtained only between 500 and 1000 Hz.

5. The 6 cc coupler is suitable only for headphone measurements and is not capable of performing the other functions expected of an aural simulator, such as attenuation measurements and "equal-loudness" listening.

6. Diffraction effects, such as occur in the "real ear" case are not accounted for with the coupler alone.

Similarly, an investigation of other couplers such as the 2 cc and 1 cc models showed that they likewise do not provide a true simulation of real ears. Therefore, it was decided that a new system of aural simulation was necessary to duplicate the human ear listening response.

Mechanical and Acoustical Properties of the Ear

It was found in the literature(4,5,6) that the human ear canal consists of a nearly cylindrical tube approximately 2.2 cm in length and 0.76 cm in diameter with a volume of approximately 1 cc. A detailed study of the properties of the ear by Zwislocki(7,8,9) reported a volume of approximately 1.6 cc for the combination of the ear canal and eardrum, which indicated that the equivalent volume* of the eardrum alone is about 0.6 cc. The same study found the resistance to lie between 400 and 500 Rayls (cgs).

Two papers by Weiner and Ross(10,11) contain data measured on human listeners and give the transfer function** for the ear canal (Figure 2). From these data, it was possible to construct the Aural Simulator which is described in the following sections.

---

*It may be shown that the equivalent volume of a diaphragm is given by the formula:

$$V_{equiv} = \rho C^2 A^2 C_M$$

where:

V_{equiv} is the equivalent volume in CC
ρ is the density of air
C is the velocity of sound in air
A is the area of the eardrum
C_m is the mechanical compliance of the eardrum

**Transfer Function = Ratio of sound pressure at ear drum to sound pressure at entrance of canal.

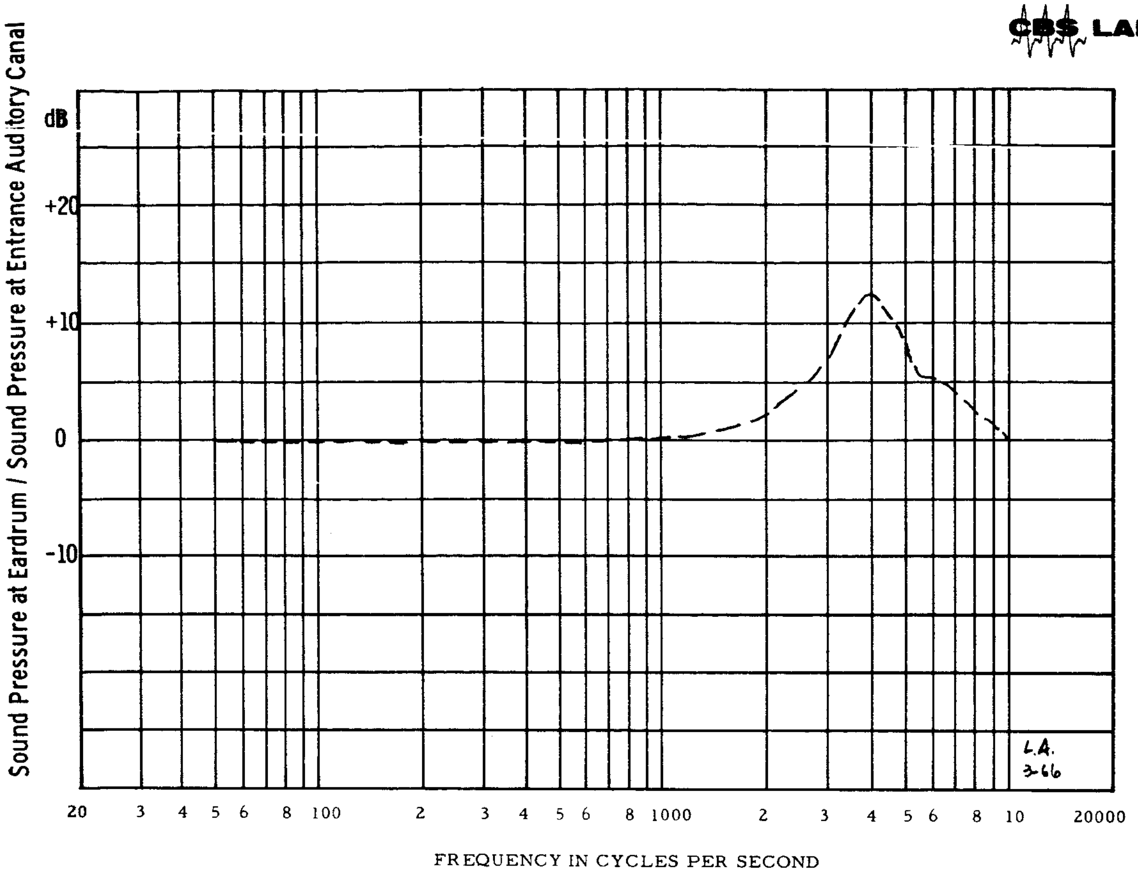


Figure 2. Real Ear Transfer Function as Measured by Weiner and Ross

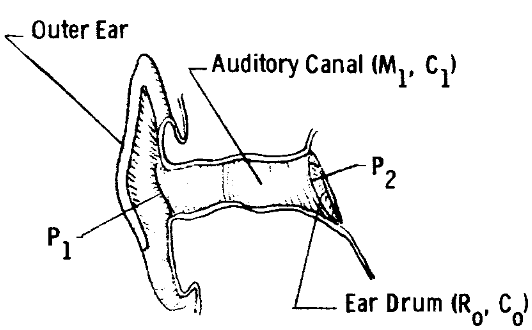


Figure 3a. Cross-Section View of Real Ear Showing Auditory Canal and Ear Drum

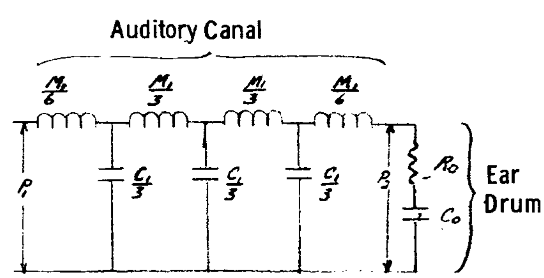


Figure 3b. Equivalent Analog Circuit of Auditory Canal and Ear Drum

Equivalent Circuit Analysis

In order to facilitate the design of the Aural Simulator, an equivalent circuit was derived which represents the electrical analog of the ear canal and eardrum. Figure 3a shows the real ear, and Figure 3b its equivalent analog circuit. It may be shown[8] that the ear canal may be approximated by lumped constant parameters which are derived from the inertance (acoustical mass) M_1 and compliance C_1 of the canal. The termination of the canal is derived from the eardrum impedance, or in the simulated case, from the acoustical impedance and acoustical resistance at the end of the canal.

The exact value of resistance, R_0, was not known, but was rapidly found by use of this circuit, thereby eliminating a time-consuming series of acoustical measurements. Figure 4 shows the transfer function (20 log P_2/P_1) obtained when the optimum value of R_o was found. Also shown is the real ear transfer function, as measured by Weiner and Ross.[10] The close agreement is an indication of the validity of this approach.

Further use was made of the equivalent circuit for formulating the Aural Simulator design. Figure 5 gives the originally intended design for the Aural Simulator. As shown, the measuring microphone was located at the rear of the ear canal, directly behind a small cavity and acoustical resistance representing the eardrum impedance. Equivalent circuit analysis indicated that the proper transfer function (P2/P1) was achieved

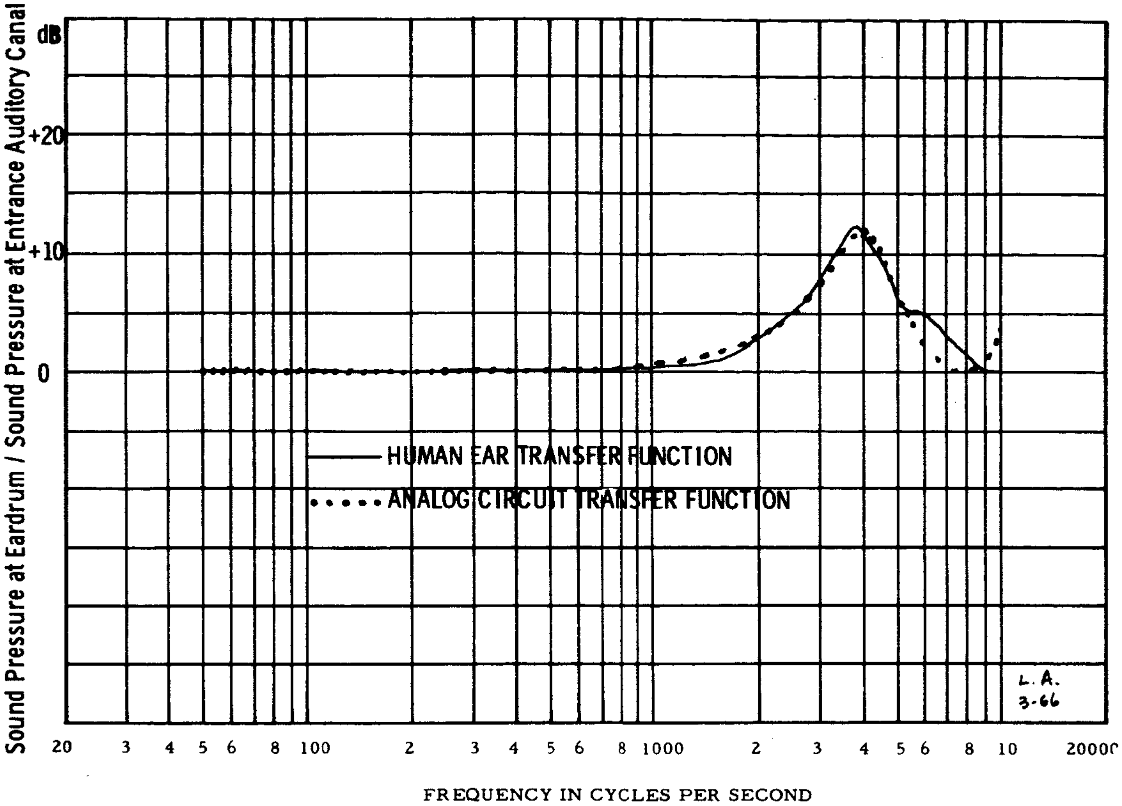


Figure 4. Transfer Functions of the Human Ear and the Analog Ear Circuit

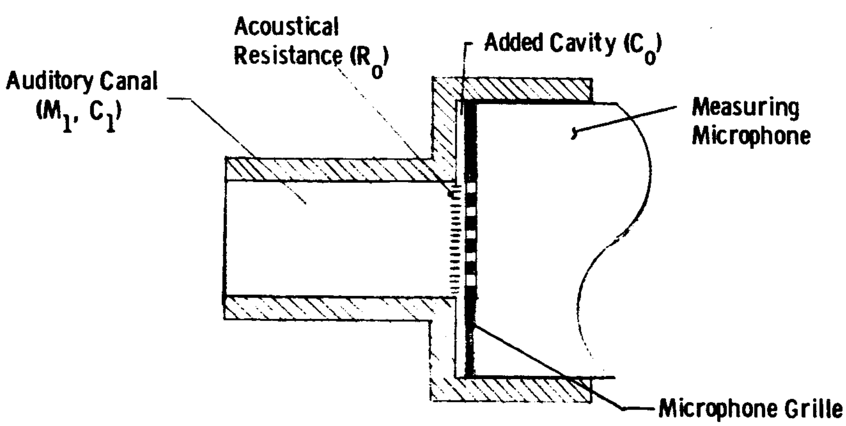


Figure 5. Original Design Conception for Aural Simulator

with this configuration. However, since the measuring microphone* is located in the rear cavity, its response was found to fall at 6 db/octave with respect to the pressure P2 (i.e. in front of the "eardrum") at frequencies above 300 Hz (see Figure 6). An equalization network could have been used at the microphone output to correct for this loss, but this technique in effect would limit the threshold of the Aural Simulator since the signal-to-noise ratio would be reduced. It was necessary, therefore, to simulate the ear canal in such a way as to permit the microphone to measure the pressure in front of the eardrum.

The modified design of the ear canal is shown in Figure 7. It is seen that the microphone is again located at the end of the canal, but the added volume and resistance representing the effect of the eardrum are around the periphery of the canal rather than directly in front of the microphone. Analysis and measurements with the equivalent circuit indicated that this approach yielded the proper acoustical characteristics, provided that the mechanical impedance of the microphone exceeded the equivalent impedance of the eardrum. This approach was implemented with the prototype ear canal, as described in the following section.

---

*In order to properly simulate the impedance of the eardrum, the mechanical impedance of the microphone itself must be as high as possible. In the analysis shown here, this impedance was assumed to be infinite.

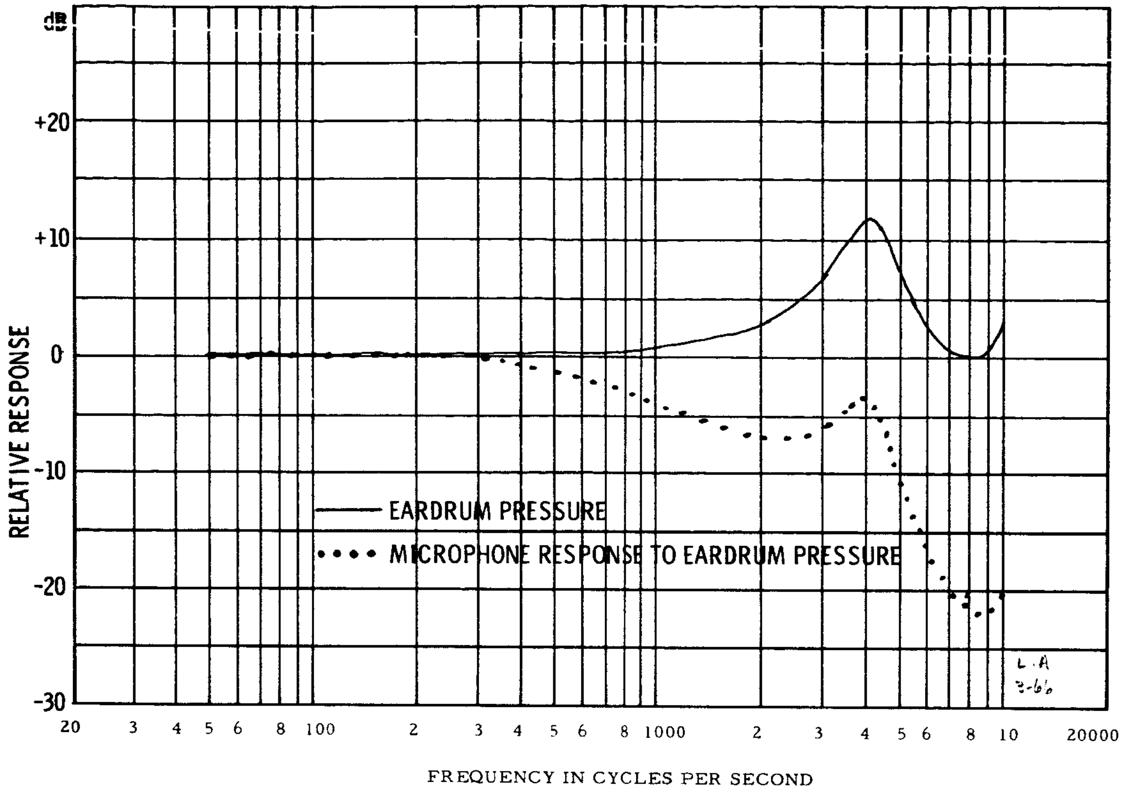


Figure 6. Response of Measuring Microphone to Eardrum Pressure Compared with Actual Eardrum Pressure

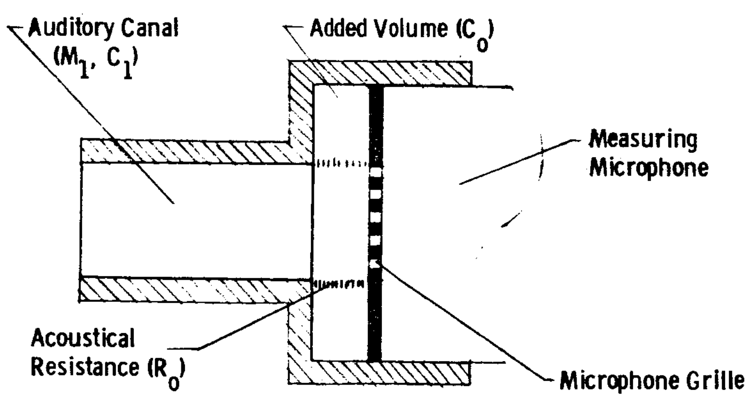


Figure 7. Modified Version of Aural Simulator

Construction and Testing of Prototype Ear Canal

A prototype ear canal was constructed in accordance with the modified design described above. However, before any acoustical tests were made on this canal it was necessary to select a microphone which would perform suitably in the circuit. Three factors governed the choice of this microphone. From the analog circuit analysis it was known that the microphone should appear as a very high mechanical impedance so that the proper eardrum compliance and resistance could be developed external to the microphone. Also, the microphone should have a "flat" pressure response free of irregularities and covering the desired frequency range. Lastly, good sensitivity and stability were necessary since the aural simulation system was to be a high quality measuring tool capable of response to a wide range of sound pressure levels. Two microphone types were found which would satisfy these criteria, namely electrostatic and piezo-electric.

A high quality version of each type microphone, a Bruel and Kjaer 4132 condenser microphone and a General Radio 1560-P6 ceramic model, were obtained for evaluation. It was found that both of these microphones had sufficiently high mechanical impedance, and both had wide-band frequency responses, although the condenser microphone exhibited less irregularities (see Figures 8 and 9). However, it was noted that the condenser microphone had a smaller equivalent volume of the diaphragm and was felt to be somewhat more stable than the ceramic unit. Therefore, the condenser microphone was chosen for use in the artificial ear canal.

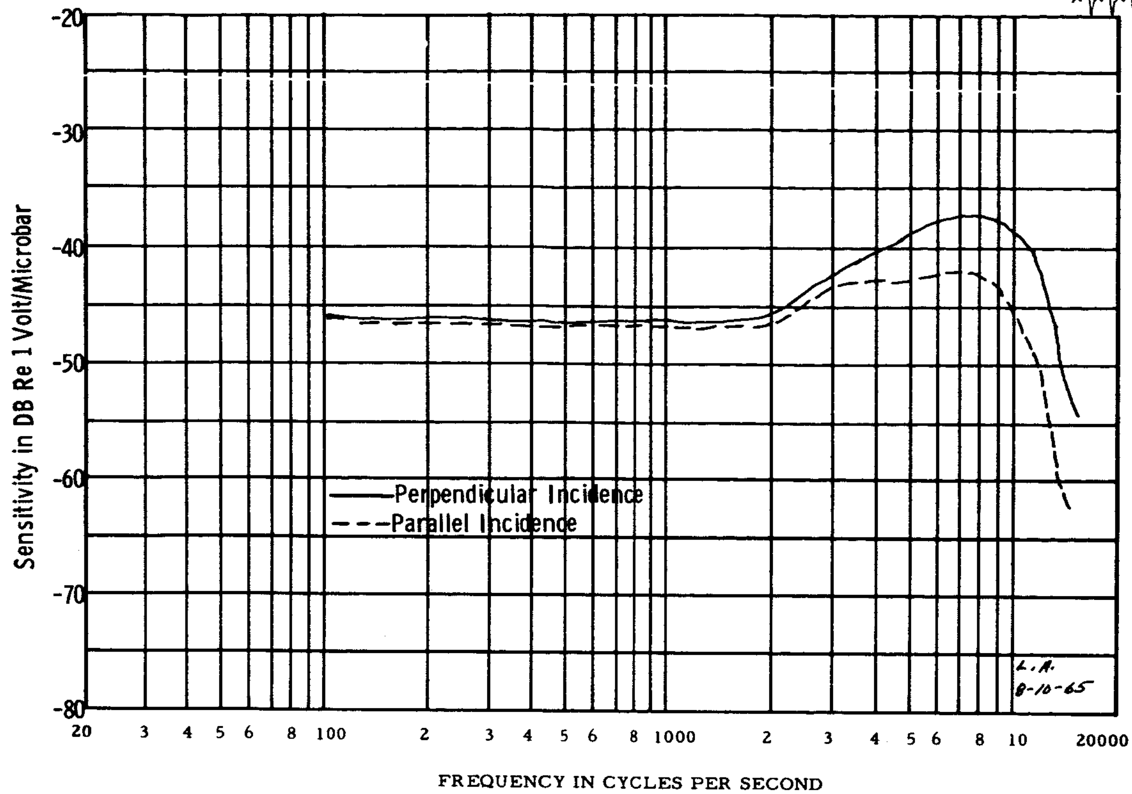


Figure 8. Free-Field Response of B and K 4132 Condenser Microphone

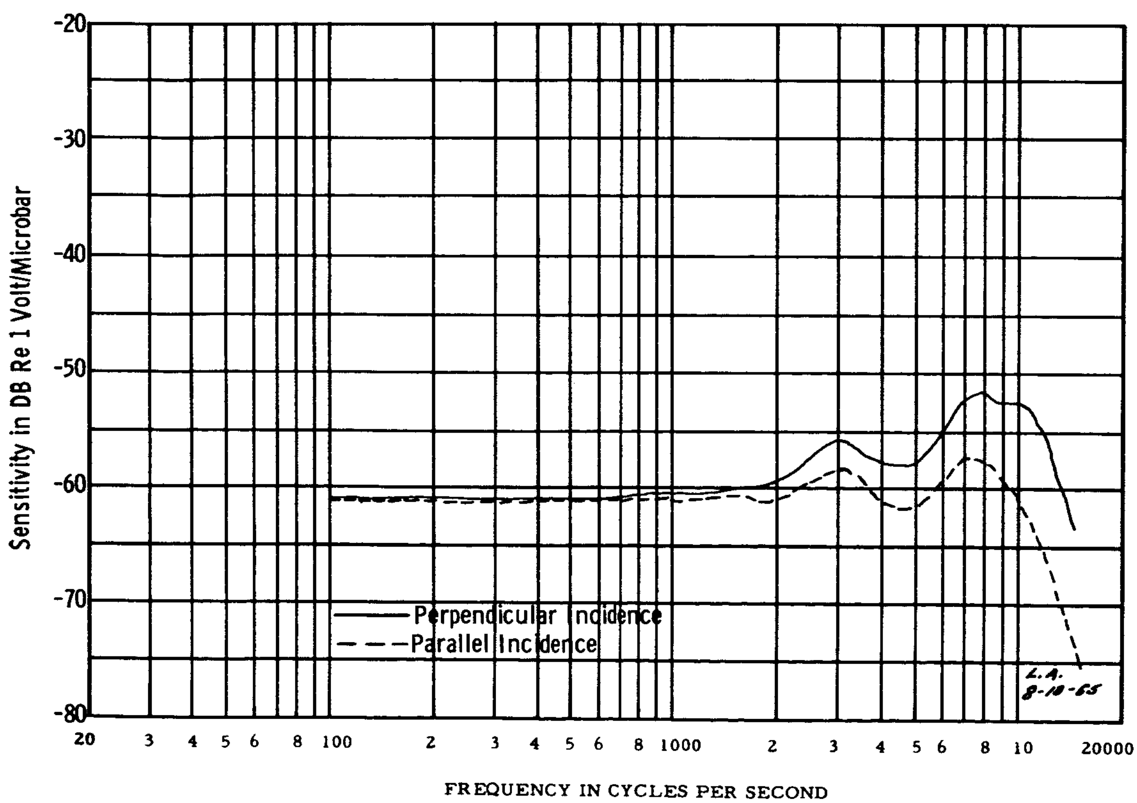


Figure 9. Free-Field Response of G R 1560-P5 Ceramic Microphone

Acoustic tests were then performed on the prototype ear canal with a calibrated probe microphone (B & K 4134). The sound pressure at the entrance of the ear canal and the sound pressure at the eardrum were measured as a function of frequency with the probe. From these data, the transfer function of the ear canal was obtained, and compared to that of the real ear[10] (Figure 10). The close agreement of these curves indicated that the prototype canal properly simulated the real auditory canal.

Next, the sound pressure at the eardrum was measured using the ear canal microphone, and compared with the eardrum pressure previously obtained with the probe microphone (Figure 11). Again, the two curves agreed closely confirming that the ear microphone was accurately measuring the eardrum pressure. These tests showed that a successful duplication of the ear canal had been achieved.

VOCAL SIMULATOR

General

The Vocal Simulator was designed to meet a set of stringent requirements, as set forth in the contract:

1. Frequency response flat within ± 2 db from 300 Hz to 3000 Hz (referenced to 1 kHz response).

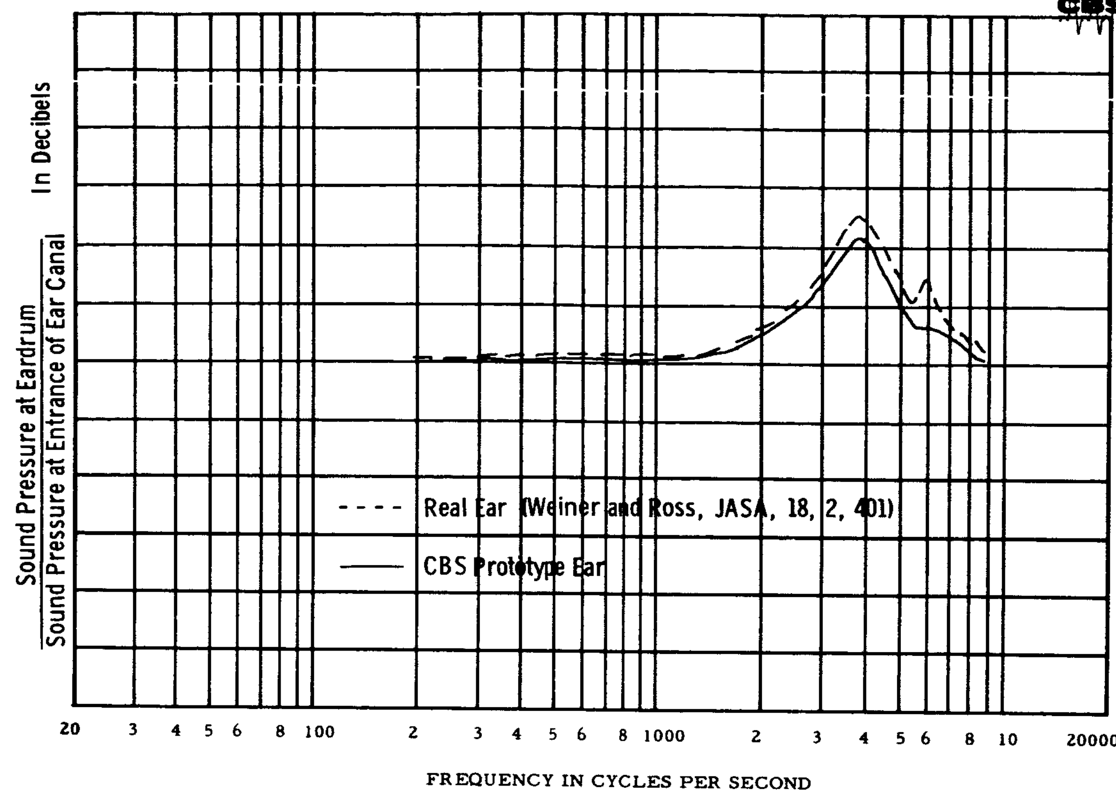


Figure 10. Ratio of Sound Pressure at Ear Drum to Sound Pressure at Entrance of Ear Canal

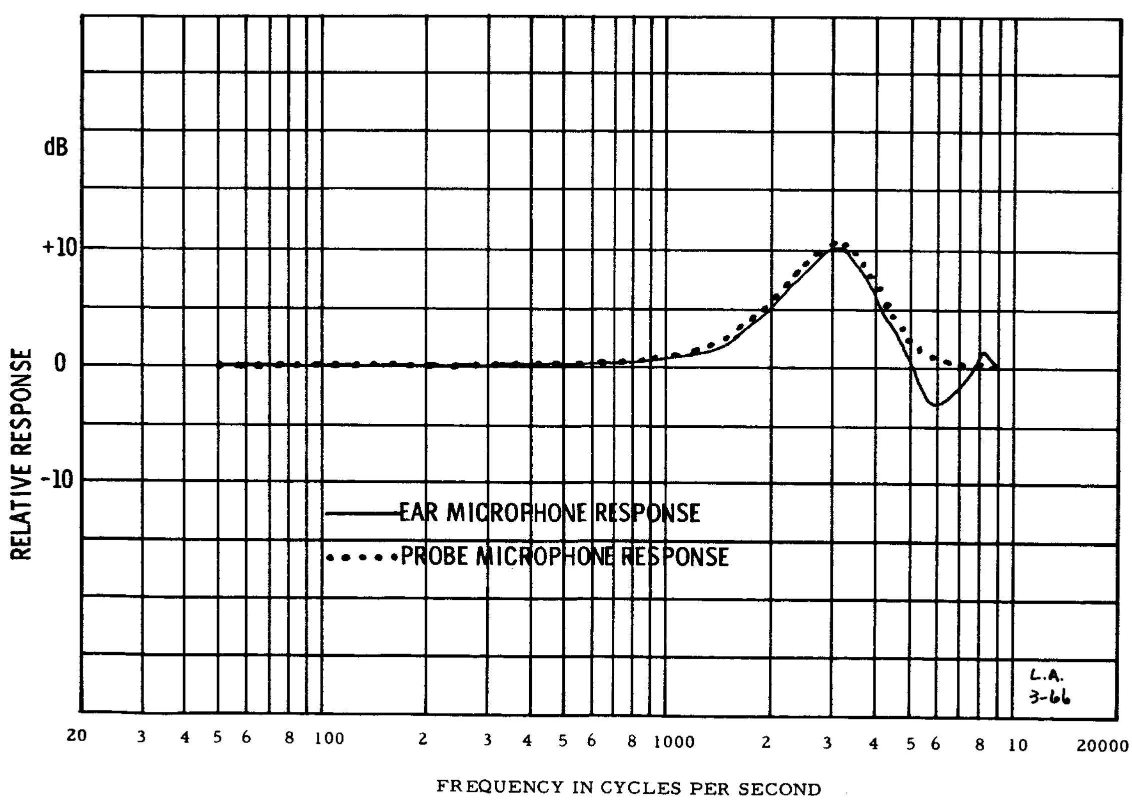


Figure 11. Eardrum Pressure in Aural Simulator as Measured by Probe Microphone and Ear Microphone

2. Vocal Simulator capable of producing an output of 100 db (re .0002 dynes/cm^2) at a distance of six inches in free field.

3. Total harmonic distortion 1% or less.

4. Speaker small enough to be located in the head or coupled to the head with suitable linkage.

Two approaches appeared to hold promise for fulfillment of these requirements. The first involved the use of a loudspeaker located in the torso, and coupled to the mouth by means of a reverse exponential horn. The primary advantage of this approach was that it allowed for a driver of substantial size since the available volume in the torso far exceeded that of the head. An alternate approach was to locate the loudspeaker in the head thus obviating a lengthy horn coupler between the speaker and mouth.

"Reverse Horn" Approach

The concept of a "reverse horn" was based upon the property of an exponential horn to transform acoustical impedance, thus providing good coupling from the driver to the mouth, as a function of frequency. Consideration of this approach proceeded with the fabrication of an exponential horn of polyester-fiberglass. The length was 29" with a 4" diameter opening at the throat and a 1/2" opening at the mouth. A mid-range loudspeaker was installed at the large end of the horn, and frequency response was measured six inches in front of the small

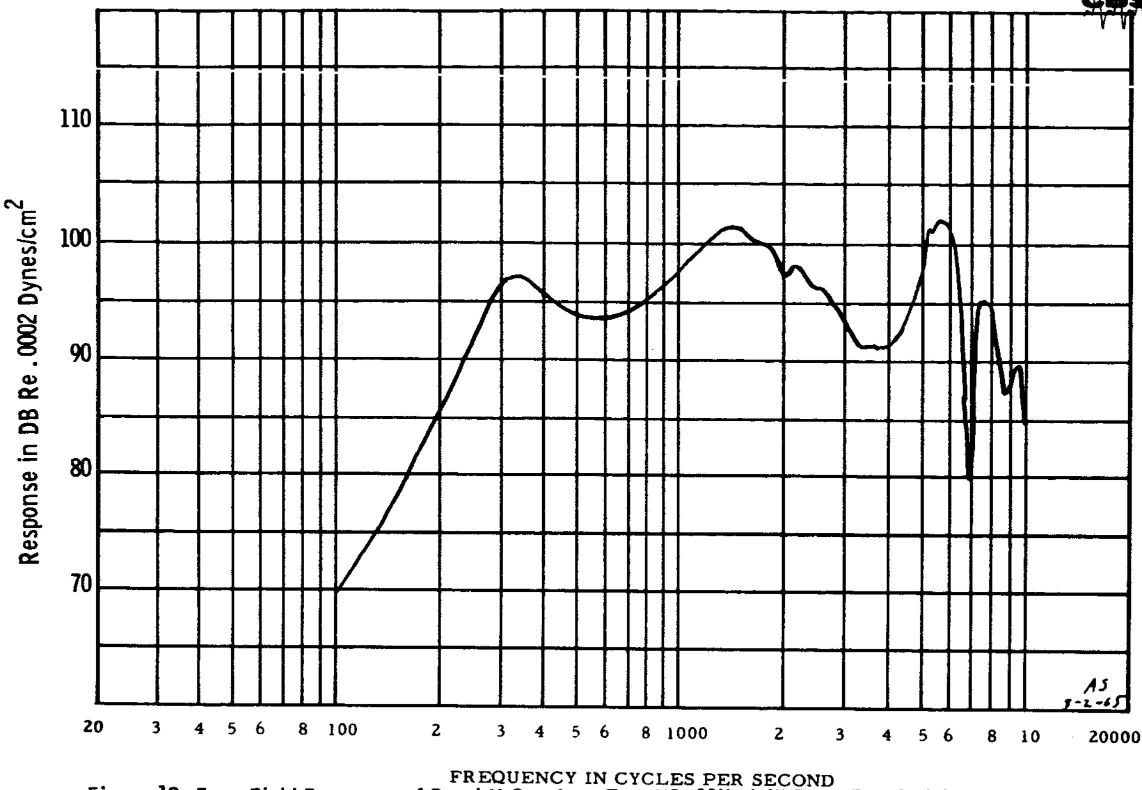


Figure 12. Free-Field Response of Band K Speaker, Type HB-0011 at 6" From Front of Speaker
Input = 1 watt

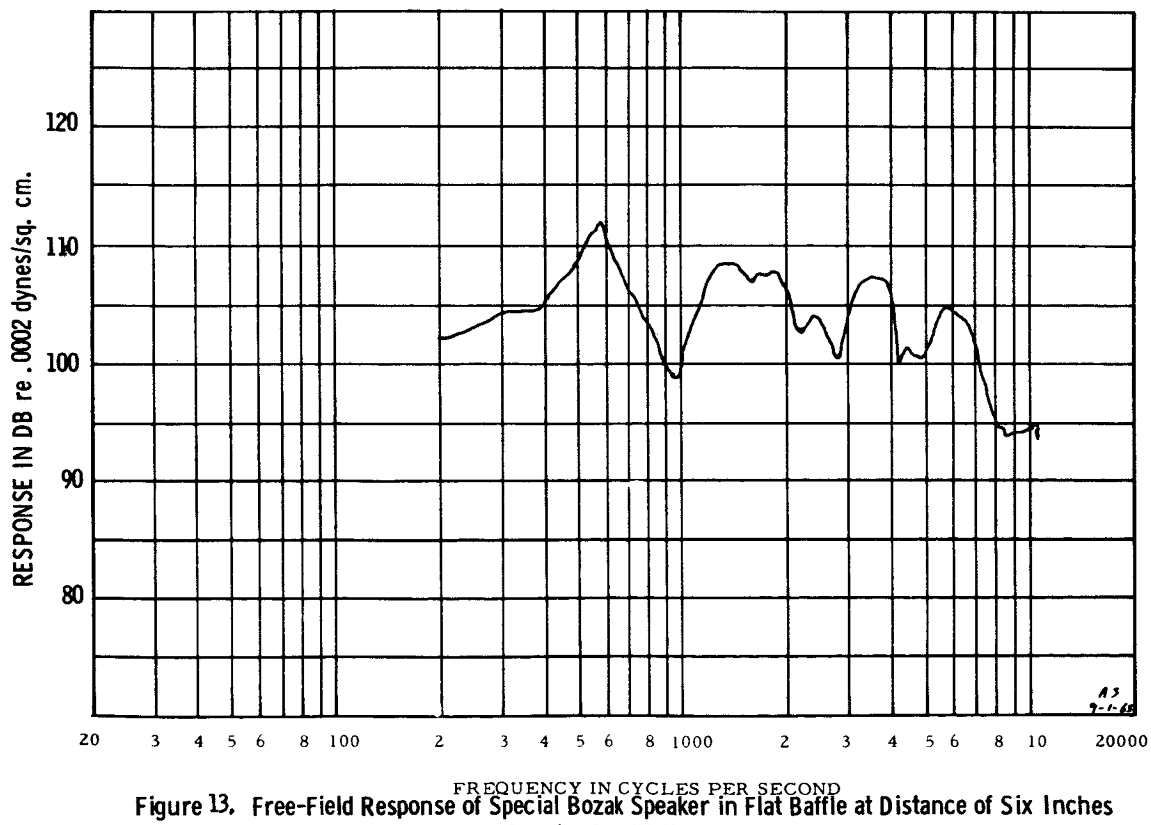


Figure 13. Free-Field Response of Special Bozak Speaker in Flat Baffle at Distance of Six Inches
Input = One Watt.

end. Measurements indicated that the horn provided the desired impedance transformation, however, in properly damping the resulting standing waves in the horn (with acoustical resistance at the mouth), a loss of efficiency ensued. In addition, a number of practical difficulties were encountered in implementing this approach, and further investigation of the exponential horn was not pursued.

Direct-Radiator Loudspeaker Approach

The second approach, that of installing a direct-radiator loudspeaker in the head, began with a survey of available small loudspeakers. Various models were evaluated, including units from Bruel and Kjaer, American Optical, Wharfdale, Quam, CTS, and Bozak. Measurements indicated that the specified sound pressure level of 100 db at six inches could be obtained with several of these. However, frequency response and distortion varied greatly among the speakers. One of the better speakers tested was a 3-1/2" diameter unit supplied by Bruel and Kjaer (Type HP-0011). Frequency response is given in Figure 12. However, distortion was 2% or greater with 100 db sound pressure at six inches from the speaker.

A small loudspeaker furnished by the Bozak Company also appeared promising, since it possessed high magnetic field strength (14,000 gauss) as is necessary for the required sensitivity and frequency response reasonably close to the requirements. Figure 13 shows the

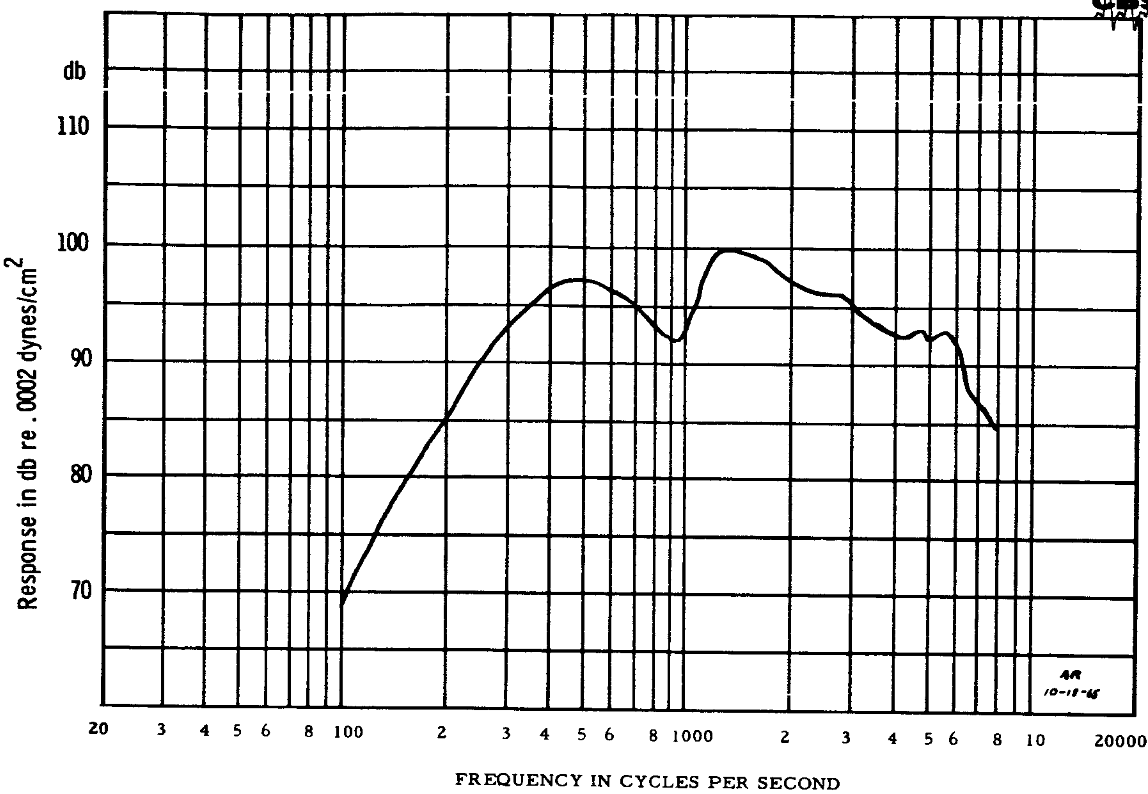


Figure 14. Free-Field Response of Model 1037-S1 Speaker at Six Inches from Front of Speaker. Input = 1 Watt

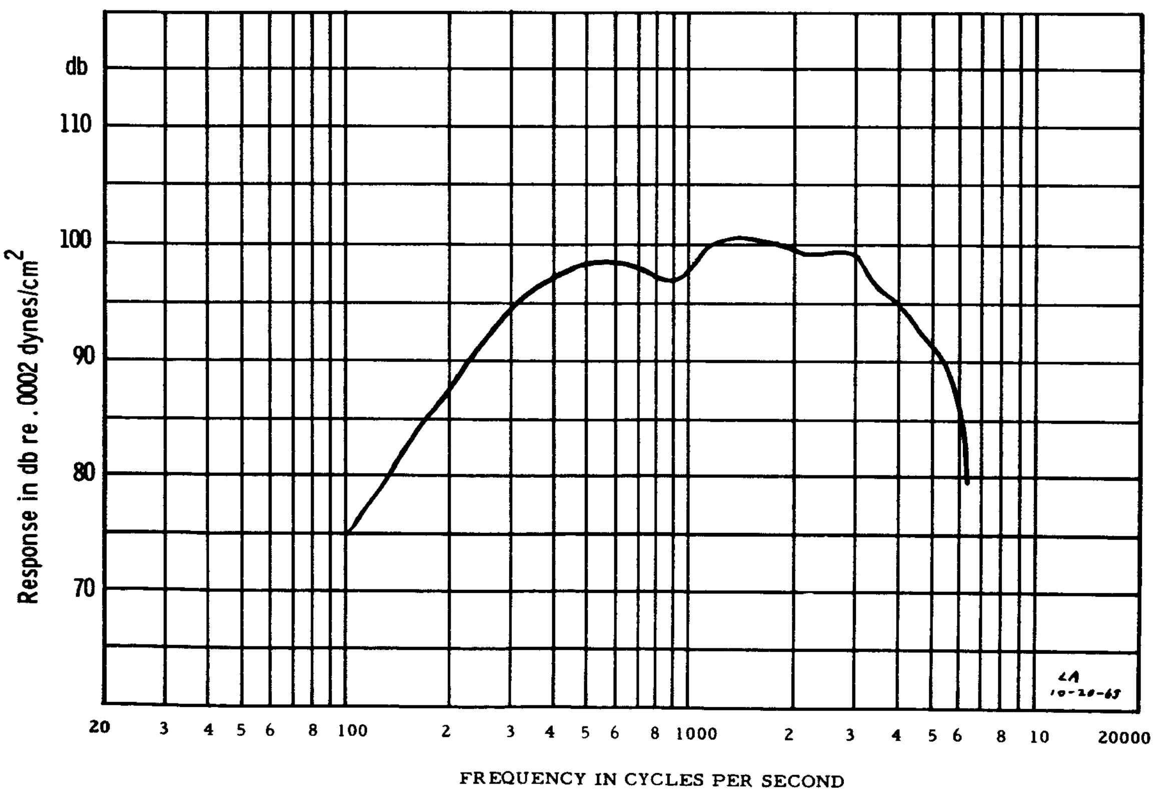


Figure 15. Free-Field Response of Model 1037-S1 Speaker with Cone Rim Sealed. Distance = Six Inches from Front of Speaker, Input = 1 Watt

response of the unit, as supplied. Investigation at CBS Laboratories revealed that the irregularities in the response were primarily due to edge reflections and cone break-up of the paper diaphragm.

Since no existing loudspeaker possessed adequate response or distortion characteristics, it was decided to redesign the latter speaker according to the specific needs of this program. Among the modifications made were the replacement of the paper diaphragm with a hemispherical shaped aluminum diaphragm, the use of a new suspension system based on tangential compliant members and carefully controlled front-to-back seal. Several models were tested, and further modifications were made, as called for. Figure 14 gives the response of an early model. As seen, the irregularities observed with the paper diaphragm were largely removed by virtue of the aluminum, dome-shaped diaphragm, although a dip in the response in the region of 1 kHz was observed. Subsequent investigation revealed this dip to be caused by inadequate damping of a suspension resonance. More complete suspension damping virtually eliminated this dip, as shown in Figure 15.

Efforts were then concentrated on developing a suitable coupler to link the speaker to the mouth. In order to avoid a loss of high frequency response, the "front volume" (between the front of the diaphragm and the inside of the coupler) must be kept as small as possible, with the constraint that the motion of the diaphragm must not be restricted.

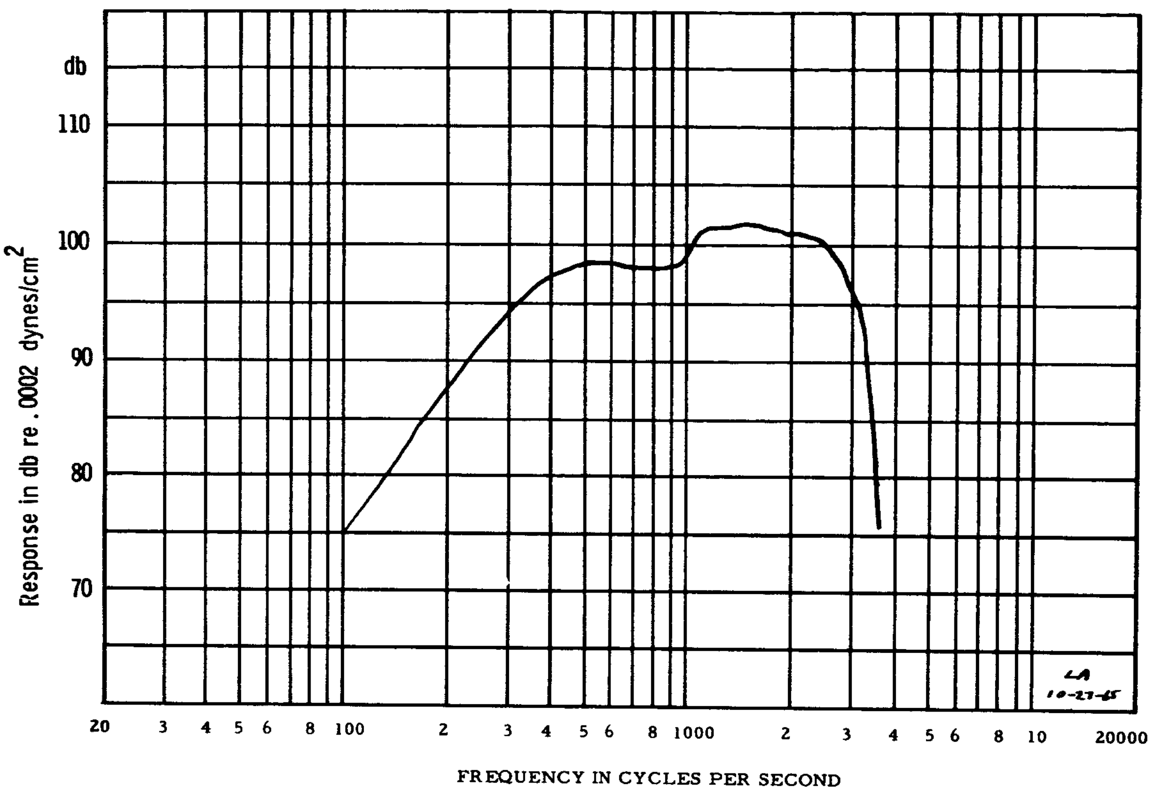


Figure 16. Free-Field Response of Model 1037-S1 Speaker in Experimental Coupler. Distance = Six Inches from Front of Speaker, Input = 1 Watt

Initial couplers were modeled of clay, and in this way, the coupler configuration was optimized. The response of the speaker in a successful early coupler is given in Figure 16.

Based upon this design, an aluminum coupler was fabricated. It was decided to provide an oval-shaped mouth opening to closely simulate the opening of a real mouth while talking. A considerable amount of damping had to be provided in order to avoid a response peak (caused by the front volume of the coupler in resonance with the inertance of the mouth opening). It was originally intended to provide this damping in the form of an acoustic screen in the coupler. However, measurements revealed that even a small amount of damping increased the harmonic distortion to above 1%. Consequently, it was necessary to make the screen acoustically transparent, and achieve the required response equalization electrically. Final response curves of the completed vocal simulator installed in the Electronic Dummy are given in Figure 27.

BIBLIOGRAPHY

1. D. Martin and L. Anderson, Headphone Measurements and Their Interpretation, J. Acoust. Soc. Am., 17:101 (1945).

2. M. Burkhard and E. Corliss, Earphone Sound Pressures in Ears, J. Acoust. Soc. Am., 23:632 (1951).

3. M. Burkhard and E. Corliss, Observations on the Acoustic Impedance of Calibrating Couplers and Ears, J. Acoust. Soc. Am., 24:114 (1952).

4. H. Olson, Acoustical Engineering, D. Van Nostrand Co. Inc., N.Y., N.Y. (1960).

5. H. Fletcher, Speech and Hearing, D. Van Nostrand Co., N.Y., N.Y. (1929).

6. Stevens and Davis, Hearing, John Wiley and Sons, N.Y., N.Y. (1938).

7. J. Zwislocki, Impedance at the Eardrum, J. Acoust. Soc. Am., 28:773 (1956).

8. J. Zwislocki and R. S. Feldman, Some Impedance Measurements on Normal and Pathological Ears, J. Acoust. Soc. Am., 29:1312 (1957).

9. J. Zwislocki and R. S. Feldman, J. Acoust. Soc. Am., 29:349 (1957).

10. F. M. Weiner and D. A. Ross, Pressure Distribution in the Auditory Canal in a Progressive Sound Field, J. Acoust. Soc. Am., 18:401 (1946).

11. F. M. Weiner and D. A. Ross, On the Diffraction of Progressive Sound Wave by the Human Head, J. Acoust. Soc. Am. 19:143 (1947).

12. B.B.Bauer, Equivalent Circuit of a Tube or Spring, J. Acoust. Soc. Am., 38:882 (1965).

13. Fletcher and Munson, Loudness, Its Definition, Measurement and Calculation, J. Acoust. Soc. Am., 5:65 (1933).

14. Pollack, Loudness of Bands of Noise, J. Acoust. Soc. Am., 24:533 (1952).

15. Churcher and King, J. Inst. Elec. Engrs., (London) 81:157 (1937).

16. Beranek, Peterson, Marshall, and Cudworth, Calculation and Measurement of the Loudness of Sounds, J. Acoust. Soc. Am., 38:882 (1965).

INSTRUCTION MANUAL FOR ELECTRONIC DUMMY

THEORY OF OPERATION (See Block Diagram, Figure 17, and System Schematic Diagram, Appended)

Aural Simulator

The aural simulator allows the electronic dummy to "hear" as a real person. To obtain the necessary simulation two main functions of the human ear are duplicated. First, an ear canal is provided that has the same dimensions, impedance and response, as a function of frequency, as real ears. Second, the Fletcher-Munson equal loudness contours are duplicated electronically so that the ED can simulate the average male hearing response.

Figure 18a shows a picture of the ear canal used in the ED. It consists of a metal tube terminated by an acoustical network and by a B & K 4132 condenser microphone (Figure 1b). P_2 represents the pressure at the eardrum while P_1 represents the pressure at the entrance of the ear canal. The ratio (P_2/P_1) is the same in this ear as in the human ear. Figure 19 shows the transfer functions for the left and right aural simulators compared with that of real ears (after Weiner and Ross).[10,11] Since microphone has a "flat" response, it directly measures the pressure at the eardrum (P_2).

The impedance at low frequencies for this ear canal is that of a volume of 1.6 cc. One cubic centimeter of this volume is associated with the auditory canal while the remaining 0.6 cc is contributed by the eardrum termination. The acoustic resistance of this canal is

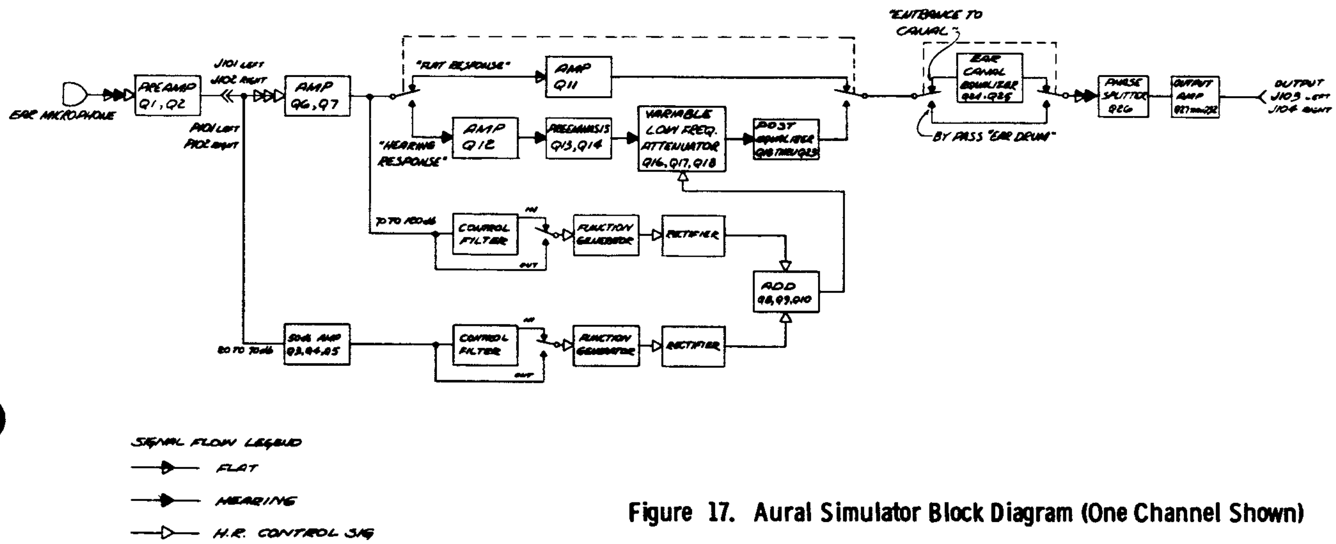


Figure 17. Aural Simulator Block Diagram (One Channel Shown)

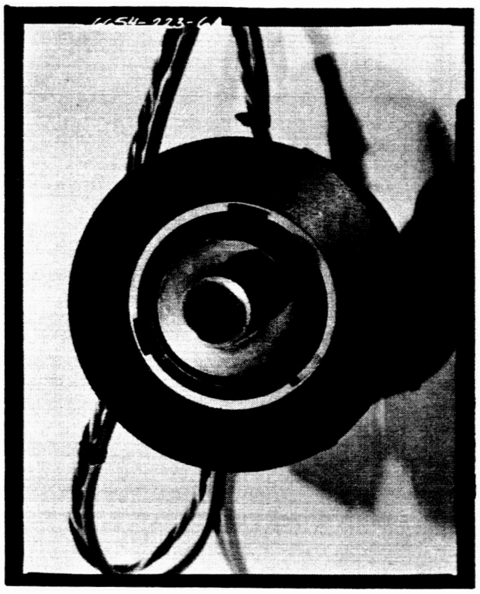


Figure 18a. Artificial Ear Canal

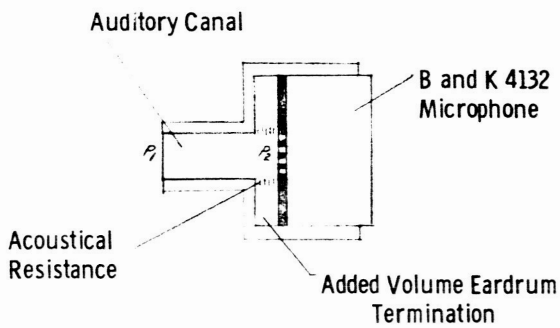


Figure 18b. Ear Canal Diagram

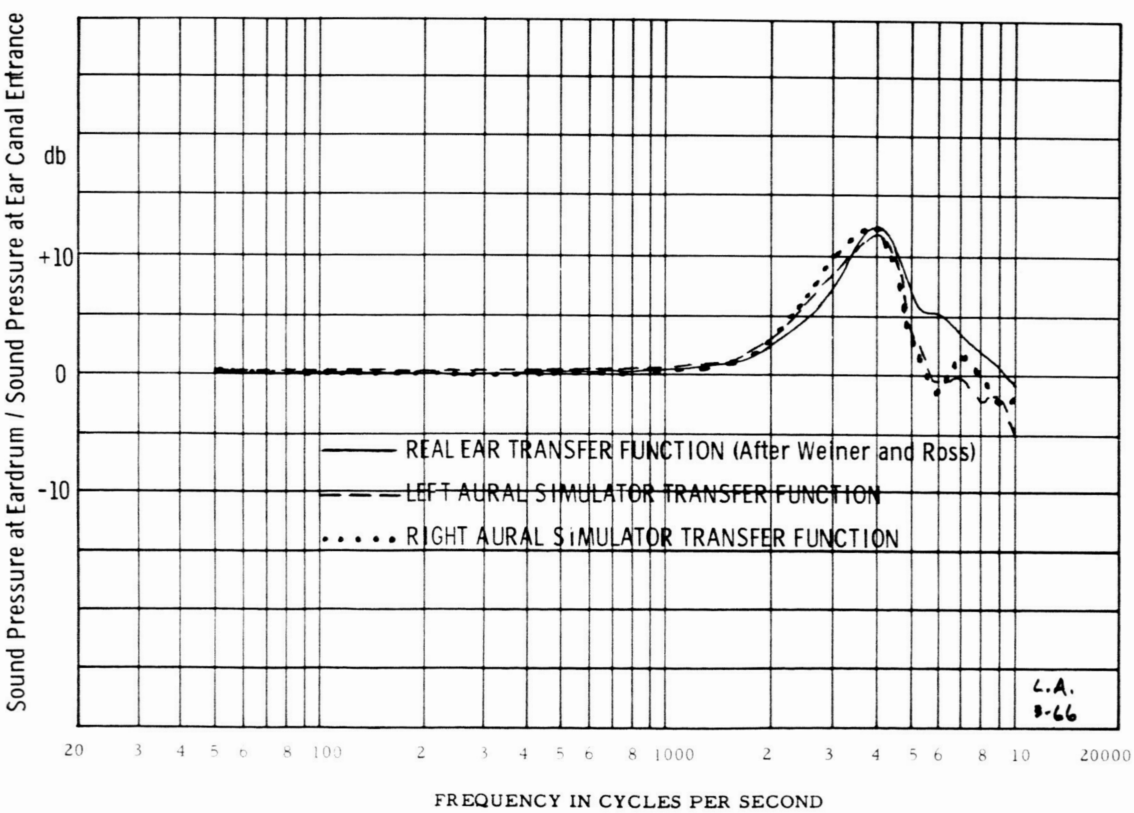


Figure 19. Aural Simulator and Real Ear Transfer Functions

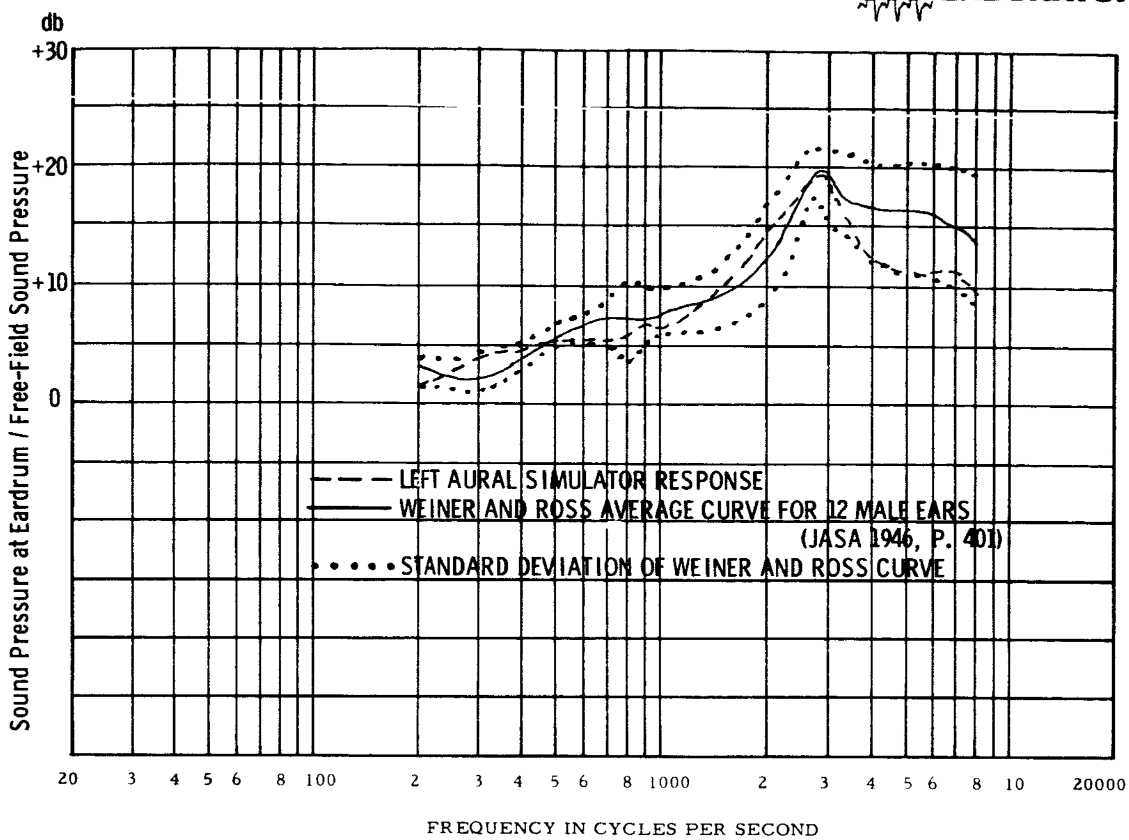


Figure 20a Comparison of Electronic Dummy Left Aural Simulator With Real Ear. Ratio of Sound Pressure at Eardrum to Sound Pressure at Center of Observer's Head (Head Removed)

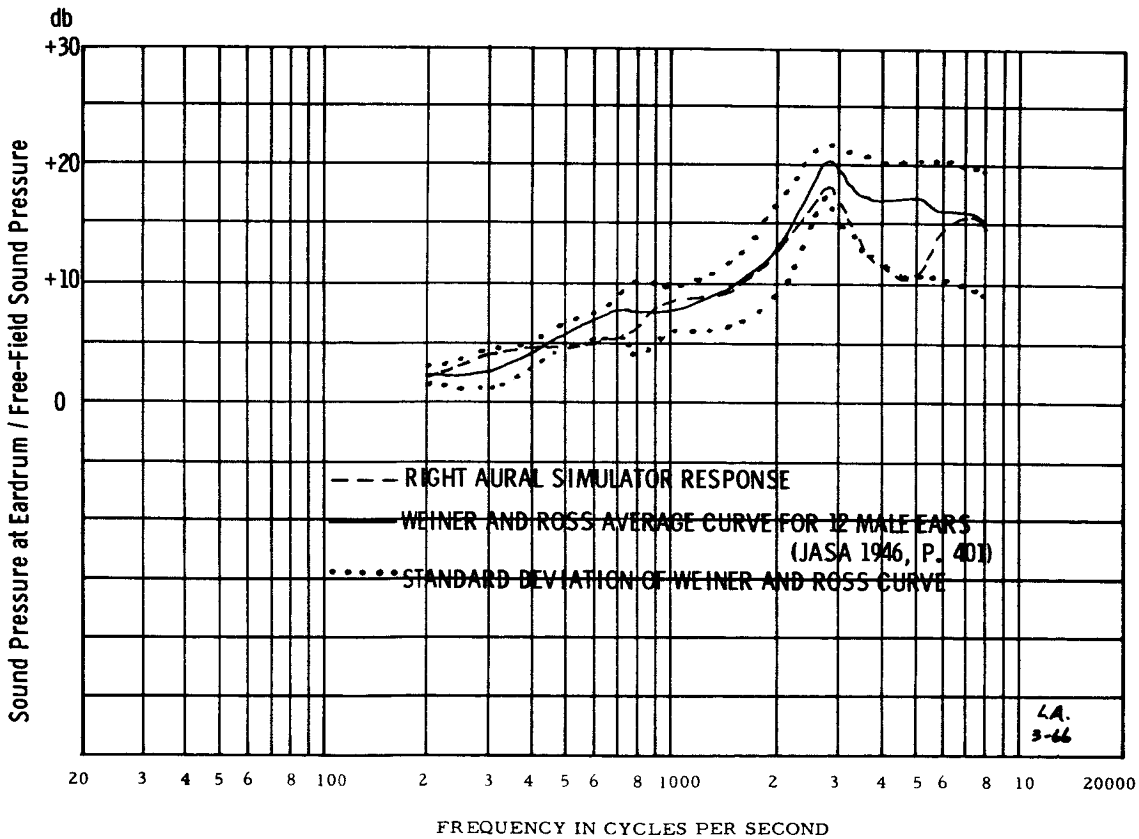


Figure 20b Comparison of Electronic Dummy Right Aural Simulator with Real Ear. Ratio of Sound pressure at Eardrum to the Sound Pressure at Center of Observer's Head (Head Removed)

400 rayls (cgs). These figures agree with those measured on real ears by Zwislocki and others. [7,8,9]

When these ear canals are placed into the head of the ED two further enhancements of the system are realized; namely, the effects of the pinna and head diffraction are included in the ear response. These effects allow the artifical ear canals to completely duplicate the response seen by real ears. Figures 20a and 20b show the Ratio of Sound pressure at the eardrum to the free-field pressure at the center of the head with the head removed for the left and right artificial ears compared to real ears. These curves include the effects of the ear canal, head diffraction, and pinna and show that the aural simulators closely duplicate the human ear canal. [10, 11]

The ear canal microphones are connected to field effect transistor preamplifiers which provide high input impedance necessary for the condenser microphones and low output impedance. The outputs of these amplifiers are connected to the main electronic chassis containing the Aural Simulator circuitry.

Hearing Response Mode

In the "Hearing Response Mode", the outputs of the ear canals are connected to amplifiers which simulate the average male hearing response as a function of sound pressure level at the ear drums. The solid arrow in the block diagram (Figure 17) shows the signal path for the Hearing Response Mode.

The output of each ear preamplifier is fed to broadband amplifiers (Q6, Q7, Q12). The signal is pre-emphasised (Q13, Q14) before feeding the Variable Low Frequency Attenuator in order to improve the signal-to-noise ratio. The Attenuator consists of four R-L stages with isolation transistors between each stage (Q15, Q16, Q17). Each inductor is returned to ground through the primary of a transformer.

The secondary of each transformer contains a vario-losser network consisting of two matched silicon diodes. By varying the DC current through these diodes in the forward direction, large changes in impedance can be obtained with relatively small changes in DC current. The diodes are used over a limited range to provide linear attenuation. The effect of the variable impedance is reflected into the primary of the transformer, and consequently varying the low frequency attenuation of the L-R network. A transformer is used to couple the vario-losser network into the primary circuit to prevent the introduction of "thump" in the signal by the changing DC current.

After processing by the variable attenuator, the signal is post-equalized by networks consisting of Q18 through Q23. The signal then feeds a phase-splitter, Q26, whose outputs feed the push-pull output amplifier consisting of transistors Q27 through Q32. The overall gain is such that at 1 kc at a sound pressure level of 95 db, the output amplifier produces 2.2 volts peak-to-peak across 600 ohms.

The Variable Low Frequency Attenuator is controlled by the DC current through each matched diode pair. By the use of zener diodes in the path of the DC control current, and by returning each diode pair to a DC potential, each vario-losser diode pair and, consequently, each R-L circuit, can be operated at different points along the range of control voltage, producing a usable attenuation-versus-control-voltage curve at any low frequency.

Function generators, using operational amplifiers with non-linear feedback, followed by full wave rectifiers are used to produce the DC control voltage. Two function generators are used per channel, each operating on 50 db of input signal (20 to 70 db and 70 to 120 db). The breakpoints of the non-linear feedback networks in each function generator are adjusted to give the required control voltage for each signal level.

The upper 50 db function generator is fed from the output of Q7 through an emitter follower (Q35). C71, R50 and R51 in the base circuit and R 70, R71 and C27 in the emitter of Q7 form a filter which optionally allows the function generator to sample only the signal in the region of 1 kc. When C72 is switched in parallel with C71 by relay K2, the low frequency response is allowed to drop to 50 cps.

The lower 50 db function generator is fed from the pre amp (Q1 and Q2) through the 50 db amplifier (Q3, Q4 and Q5). Filtering as described above is provided by R18 and C11 in the collector circuit of Q4, and R22, R23 and C12 in the emitter of Q5. C13 is switched across C12 for function generator response to 50 cps. Switching between the 1 kc narrow bandpass filter and the 50 cps-to-1 kc filter is provided by the "Control Filter IN-OUT" switch.

At levels above 70 db the lower 50 db function generator goes into saturation providing no further increase in output to its rectifiers.

The nature of the Fletcher-Munson contours is such that at the 100 db level, response is essentially flat. A bucking voltage is therefore provided and adjusted so that at the 100 db level, the resultant of the negative output of the function generator rectifiers and the positive bucking voltage cancel exactly, and the control voltage is zero. At lower signal levels the resultant output voltage is positive, reaching a maximum at the 20 db level.

At levels above 100 db (up to 120 db) the control voltage becomes negative. Q34 and its associated circuitry provide for the operation of the first R-L circuit on both positive and negative excursions of control voltages. Q34 is biased such that it is normally cut off with no control voltage applied. It remains cut off for positive control voltages. The control current is allowed to flow through R214 and R210 for positive control voltages allowing for normal operation of the vario-losser. For negative control voltages, the transistor starts to conduct producing normal control current through the vario-losser diode pair.

Flat Response Mode

In the flat response mode the outputs of the ear preamplifier are are connected directly to the line amplifier. The flat response mode has an operating bandwidth of 200 to 5000 Hz.

As indicated by Figure 17, Relays K3 and K4 allow the signal from the emitter of Q7 to by-pass the variable low frequency attenuator and its associated equalization networks. Amplifier stage Q11 and gain control R116 provide for equal gain in both the flat and hearing response modes.

Ear Canal Equalizer

The ear canal equalizer is available for use in both the hearing and flat response modes. It serves the function of electrically compensating for the effect of the ear canal resonance. When this equalizer is inserted in the signal path, in either mode, it is equivalent to physically moving the two microphones to the entrance of the ear canal. This equalizer is operated by relays K5 and K6 and controlled by the EAR DRUM - ENTRANCE TO CANAL function switch. The ENTRANCE TO CANAL position should be used for the HEARING MODE response.

Power Supplies

Three power supplies are used to supply the three operating voltages for relay switching and electronic circuitry. (+59 volts, +15 volts, and -15 volts). A DC-to-DC converter and associated circuitry provide the 200 volts bias to the condenser microphones. This converter operates from the 59-volt supply.

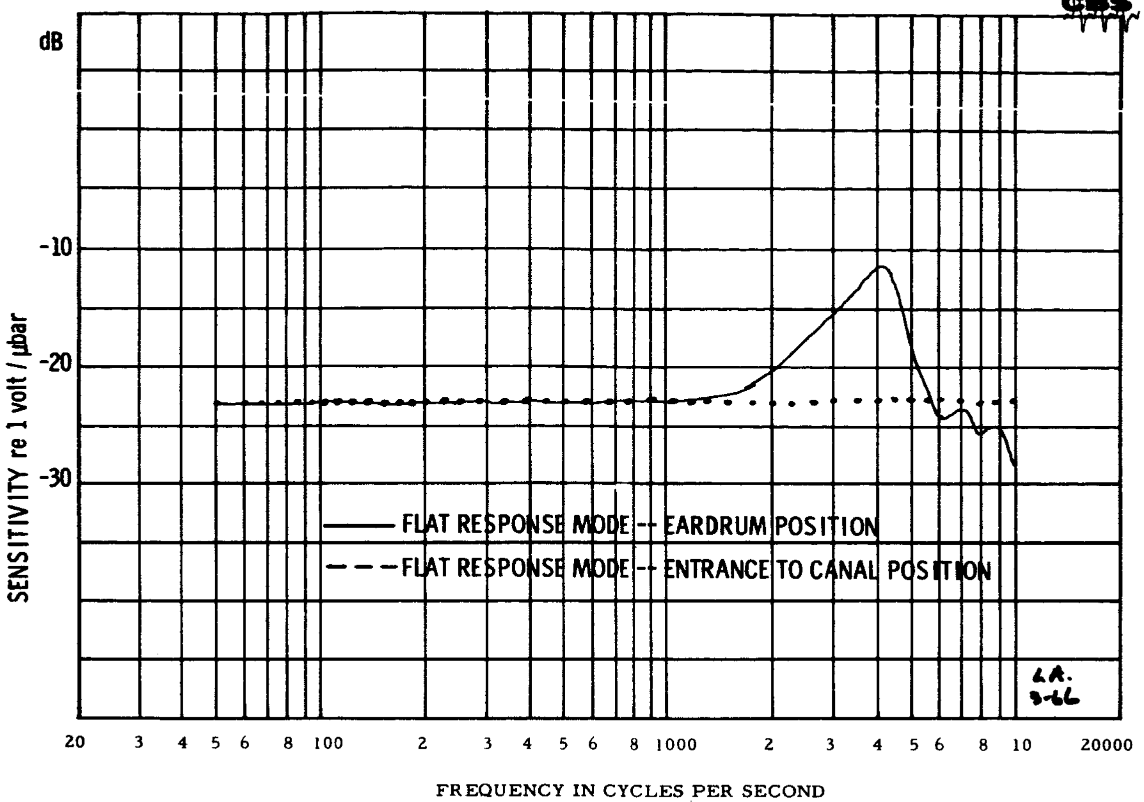


Figure 21a. Calibration of Left Aural Simulator in Flat Response Mode

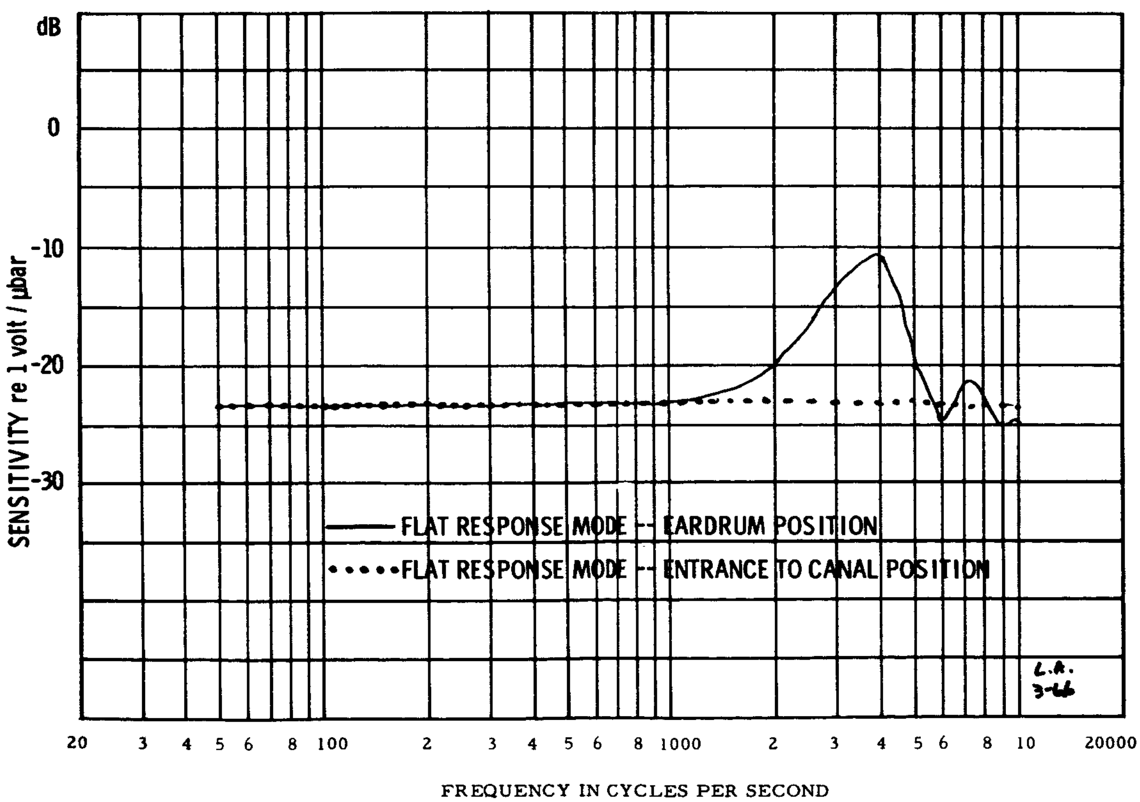


Figure 21b. Calibration of Right Aural Simulator in Flat Response Mode

Calibration Curves

Flat Response Mode - Figures 21a and 21b give the calibration of the left and right aural simulators in the EARDRUM and ENTRANCE TO CANAL positions.

Hearing Response Mode - The hearing response mode calibration is the same as the flat mode in Figure 21 for frequencies above 1000 Hz. Below this frequency, the calibration is no longer "flat" but changes as a function of input level. Figures 22 and 23 show these spectral changes as function of input level for the left and right aural simulators. As shown by these figures, measurements in the hearing response mode are limited by system hum at the 40 db level. In the flat response mode, hum is at approximately the 25 db level.

Acoustic Isolation - Acoustic Isolation of the ED is determined by placing the system in a random noise field and measuring the aural simulator output with the ear canals open and completely sealed. The difference in db between the open and sealed curves (Figure 24) represents the limiting values of attenuation the ED is capable of measuring as a function of frequency.

Vocal Simulator

The vocal simulator allows the ED to "speak" at the same level and spectrum as the human voice. The system operates with a ± 2 db response from 300 to 3000 Hz and can produce sustained sound pressure levels up to 10 db SPL. The Vocal Simulator consists of a special design moving-coil speaker and coupler (Figure 25) housed in the head, and a power

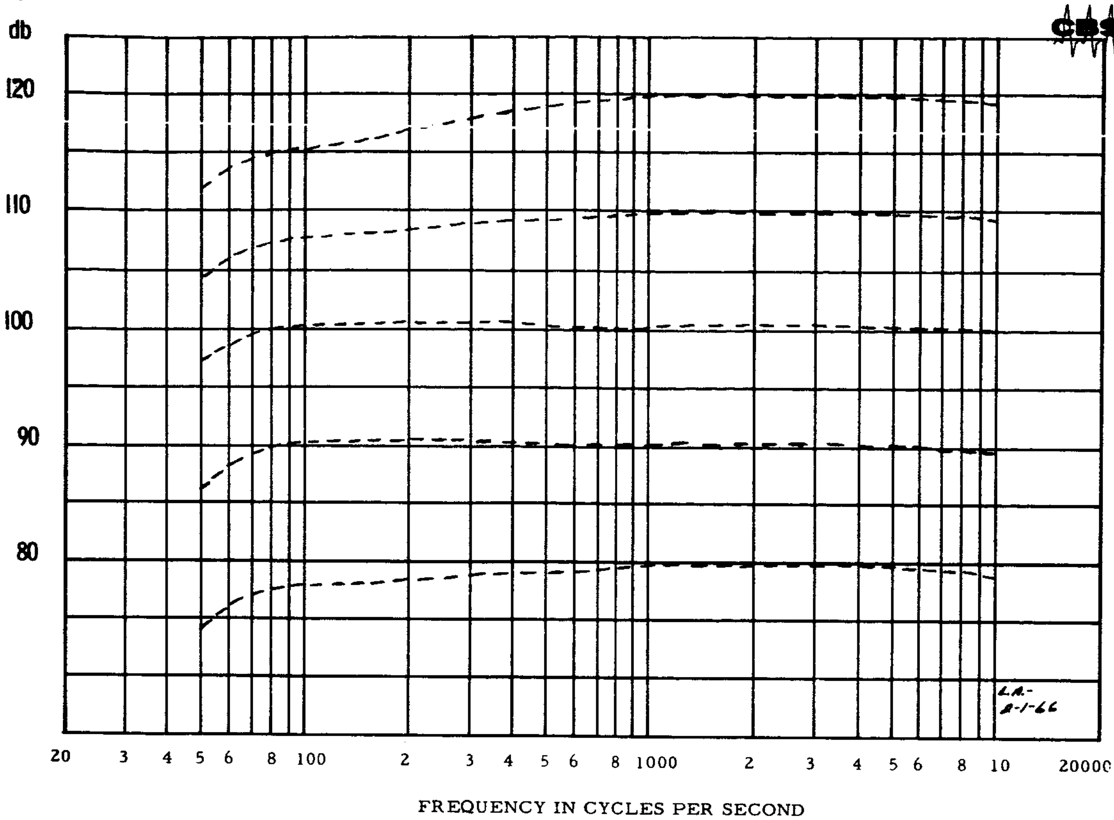


Figure 22a. LEFT EAR LOUDNESS CONTOUR EQUALIZATION (120 PHON TO 80 PHON CONTOURS)

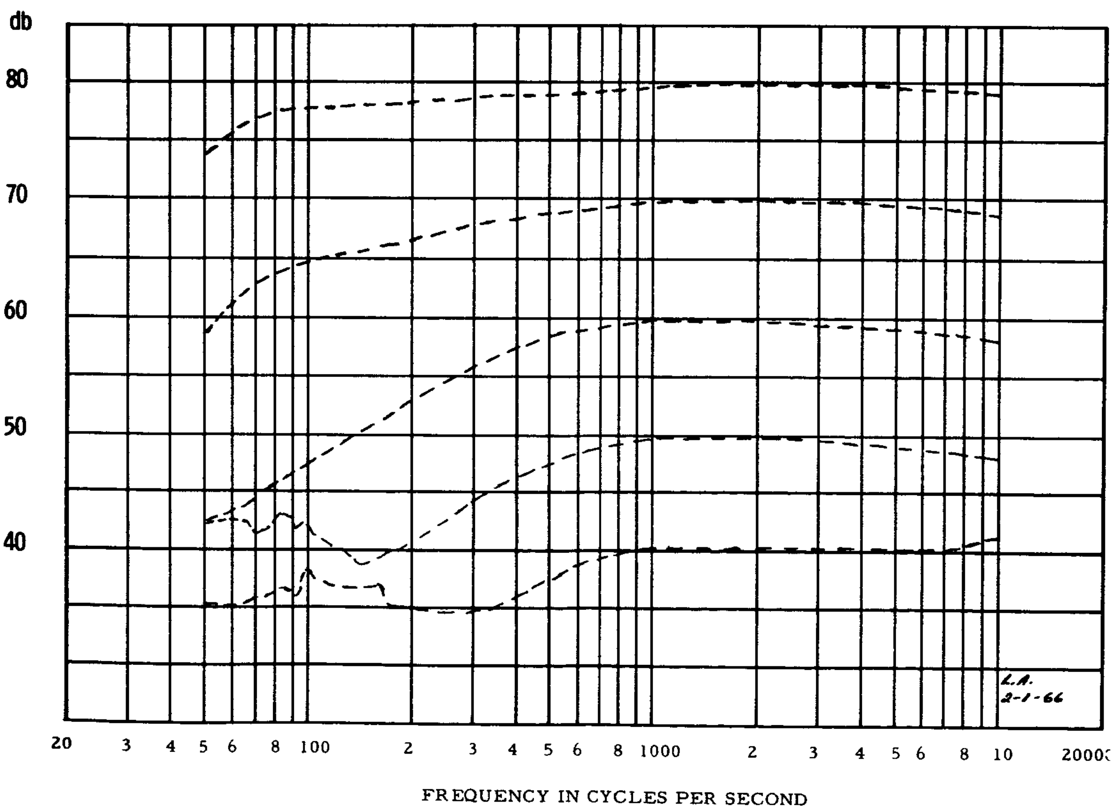


Figure 22b. LEFT EAR LOUDNESS CONTOUR EQUALIZATION (80 PHON TO 40 PHON CONTOUR)

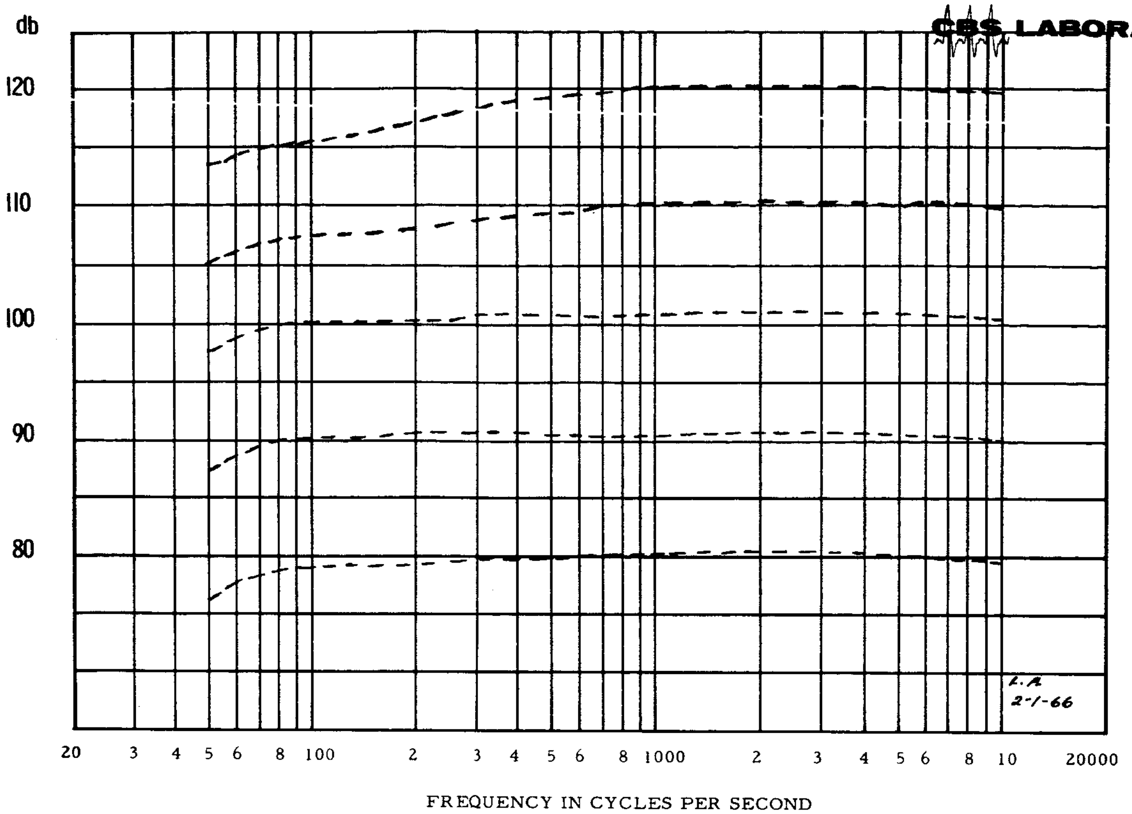


Figure 23a. RIGHT EAR LOUDNESS CONTOUR EQUALIZATION (120-PHON TO 80 PHON CONTOURS)

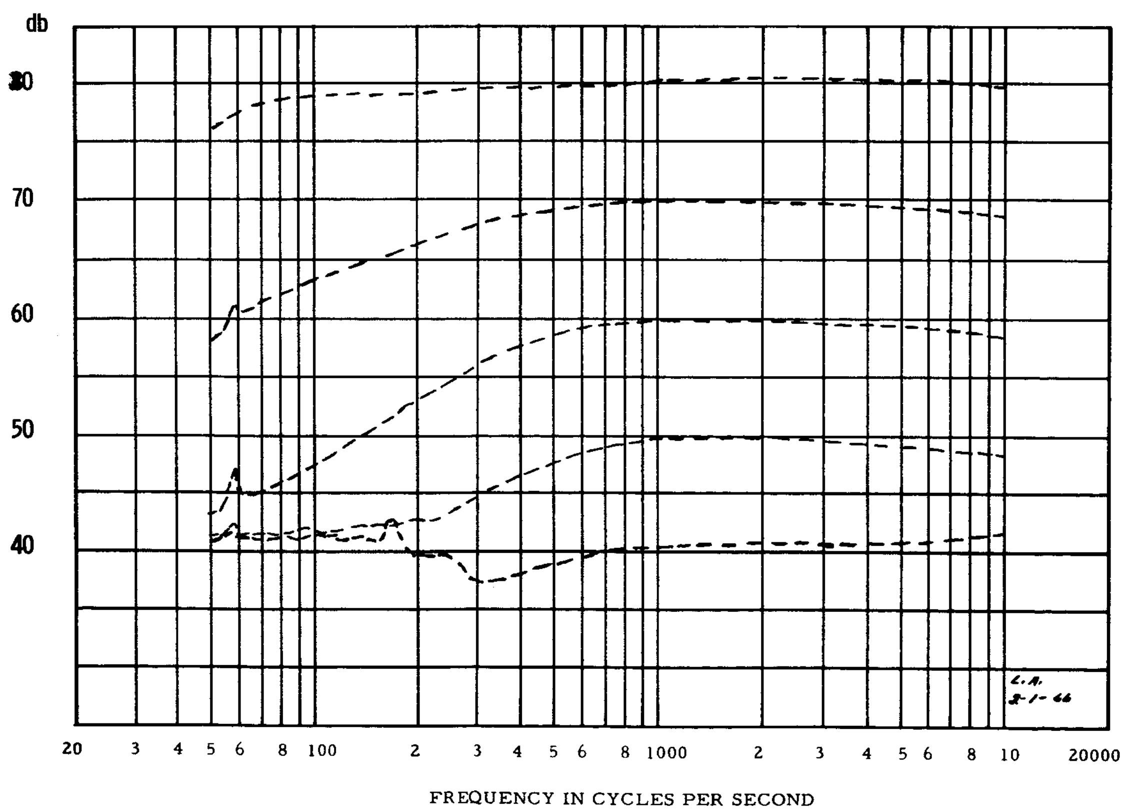


Figure 23b. RIGHT EAR LOUDNESS CONTOUR EQUALIZATION (80 PHON TO 40PHON CONTOURS)

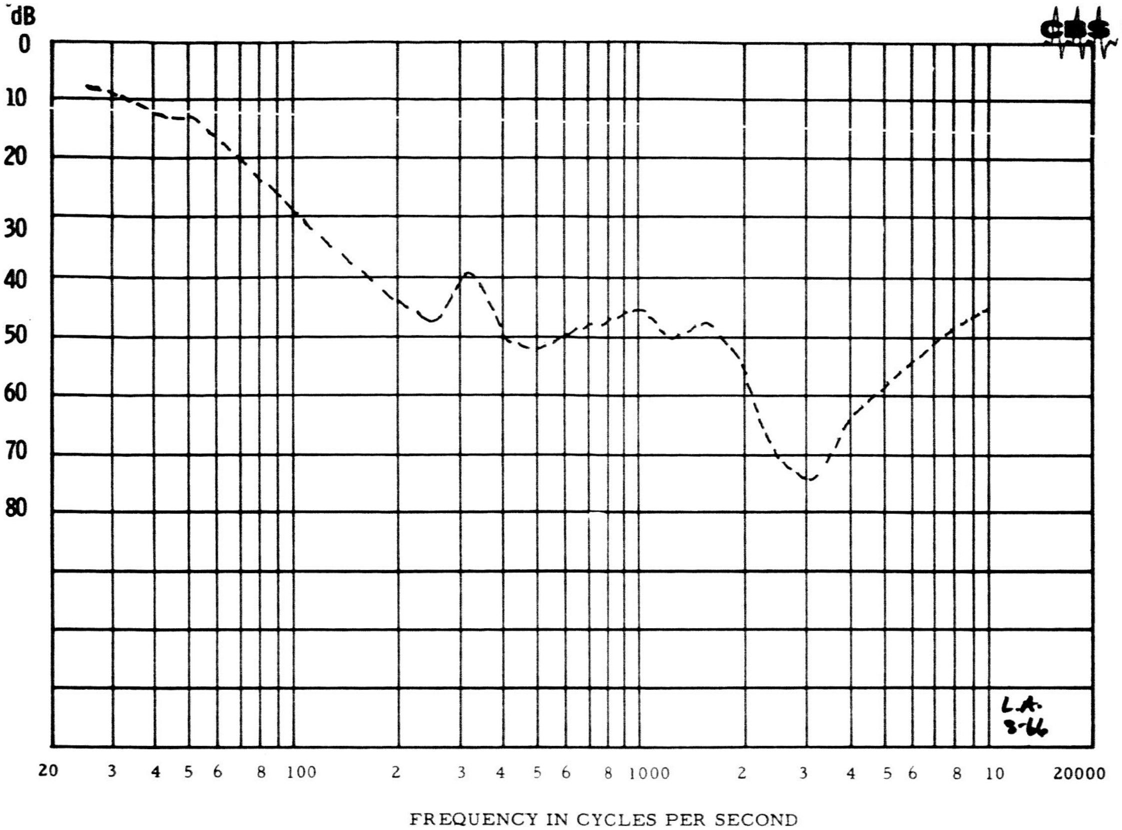


Figure 24. Isolation of ED Aural Simulator in Artificial Head

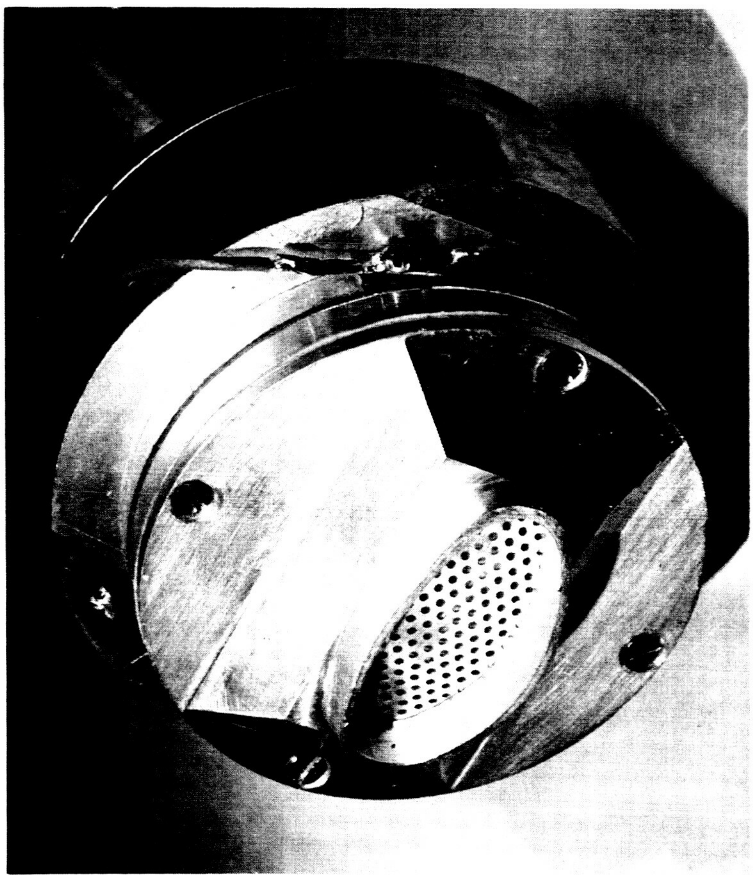


Figure 25. Mouth Speaker and Coupler of the Vocal Simulator

amplifier in the electronics chassis.

Voice Amplifier

The Voice Amplifier card contains a power amplifier with a 33 db power gain. The input impedance is within 10% of 600 ohms from 300 Hz to 3000 Hz. The frequency response is tailored to the system requirements and is -3 db at 125 Hz and 11 kHz. The SNR referred to 100 db SPL is 77 db with a floating input. The total harmonic distortion at the 10 watt level is non-measurable at 1 kHz and is less than 0.2% at 300 Hz and less than 0.15% at 3 kHz. The maximum power output of the amplifier into a 16 ohm load (without the speaker equalizer and protective network) is approximately 20 watts average (40 watt peak capability).

Referring to Figure 26, the power amplifier is a direct-coupled quasi-complementary symmetry circuit. Exceptional care has been taken in the design to achieve low distortion. Four feedback loops are used. The major negative loop returns from the amplifier output to the junction of R903, R904, and R917 and provides 20 db of feedback. R917 and C907 are in this loop and set the high frequency rolloff. A DC loop returns from the collector of Q 905 through R911 and R912 to the base of Q901. This loop controls the operating point of the entire amplifier and also adds additional AC feedback. C902 provides high frequency rolloff to the gain stage (Q901) and stabilizes the major loops. Positive feedback from the output to the junction of R915 and R916 is provided by the bootstrap capacitor C904 and serves

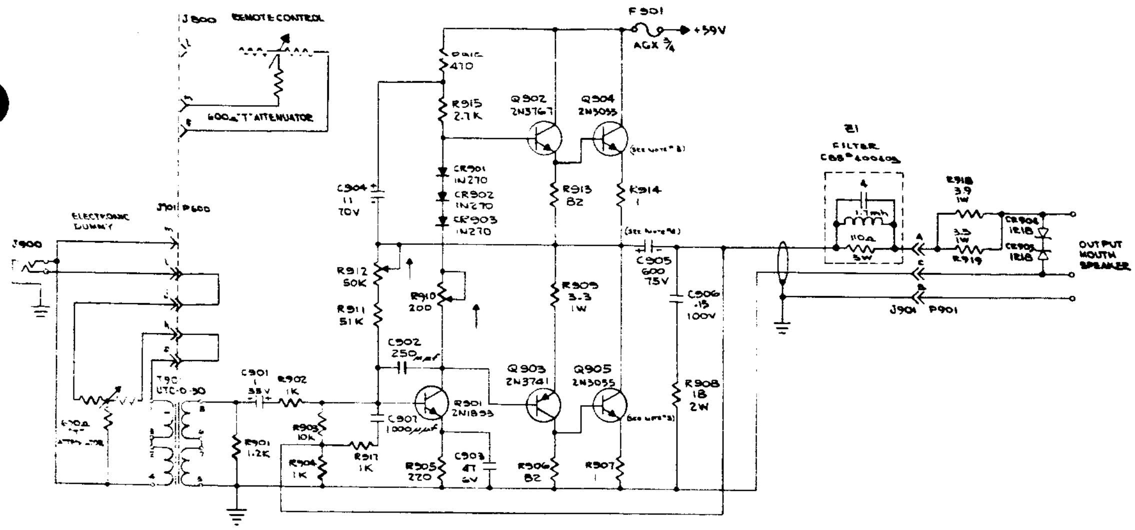


Figure 26. Schematic Diagram, Vocal Simulator

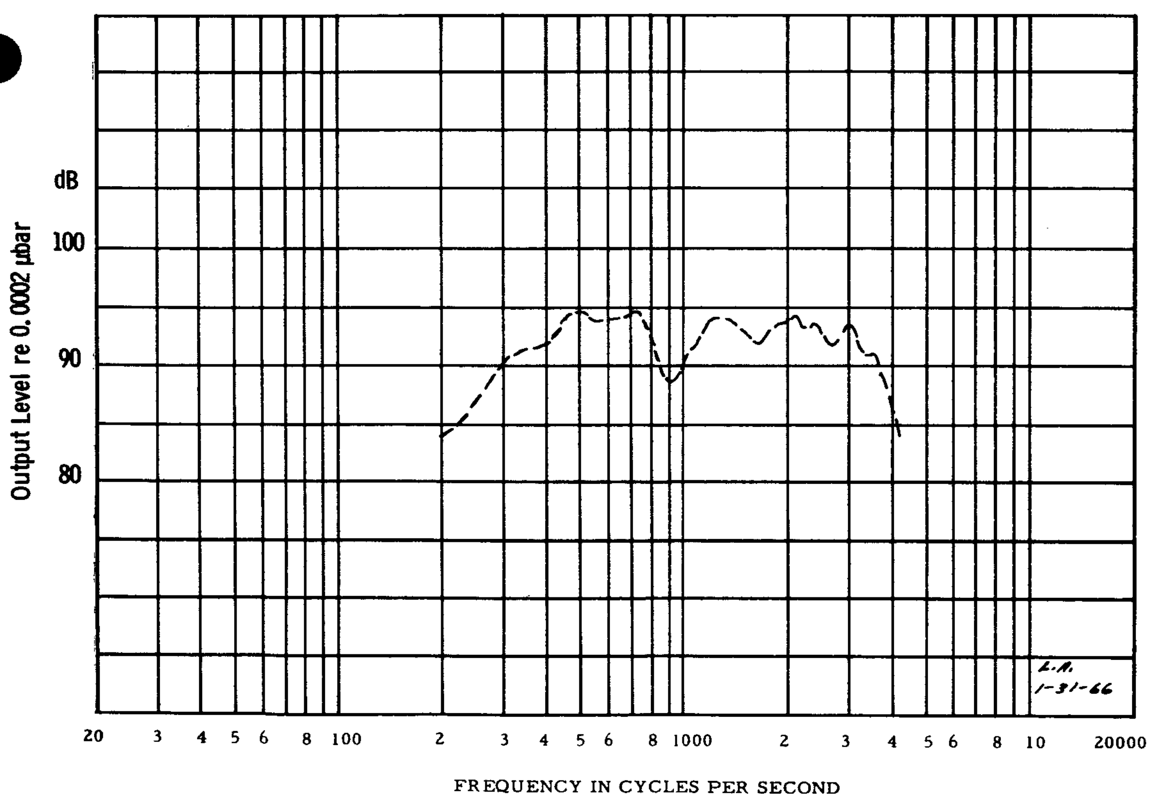


Figure 27. Frequency Response of Vocal Simulator in ED at Distance of 6" From Lips.
Input to Vocal Simulator = 2.2 volts peak-to-peak

to increase linearity at high levels. Low frequency rolloff is controlled by C901. To counteract the increased speaker impedance at ultrasonic frequencies, C906 and R908 shunt the output. The crossover bias in the output stage is controlled by R910 and is temperature compensated by the three diodes CR901, CR902, CR903.

The filter assembly (CBS assembly #400403) serves to equalize irregularities in the mouth speaker response. Finally, the zener diode circuitry R918, R919, CR904 and CR905 limits the peak power to the speaker to 20 watts. This prevents the speaker from being damaged by excessive coil displacement at low frequencies.

Calibration Curves

Figure 27 gives the response vs. frequency at six inches for the vocal simulator with an input signal of 2.2 volts peak-to-peak across the 600 ohm input and the volume control fully clockwise.

> NOTE: The vocal simulator has been designed to handle an overload steady-state input voltage 6 db higher than the input required for a 100 db output level at six inches. Exceeding this input level is not recommended and may cause damage to the vocal simulator.

OPERATION

1. Before operating the ED, check that all circuit boards are in place and (see Figure 28a) that P101, P102, P700, P901, and the Dummy Remote Plug P701 are all in place.

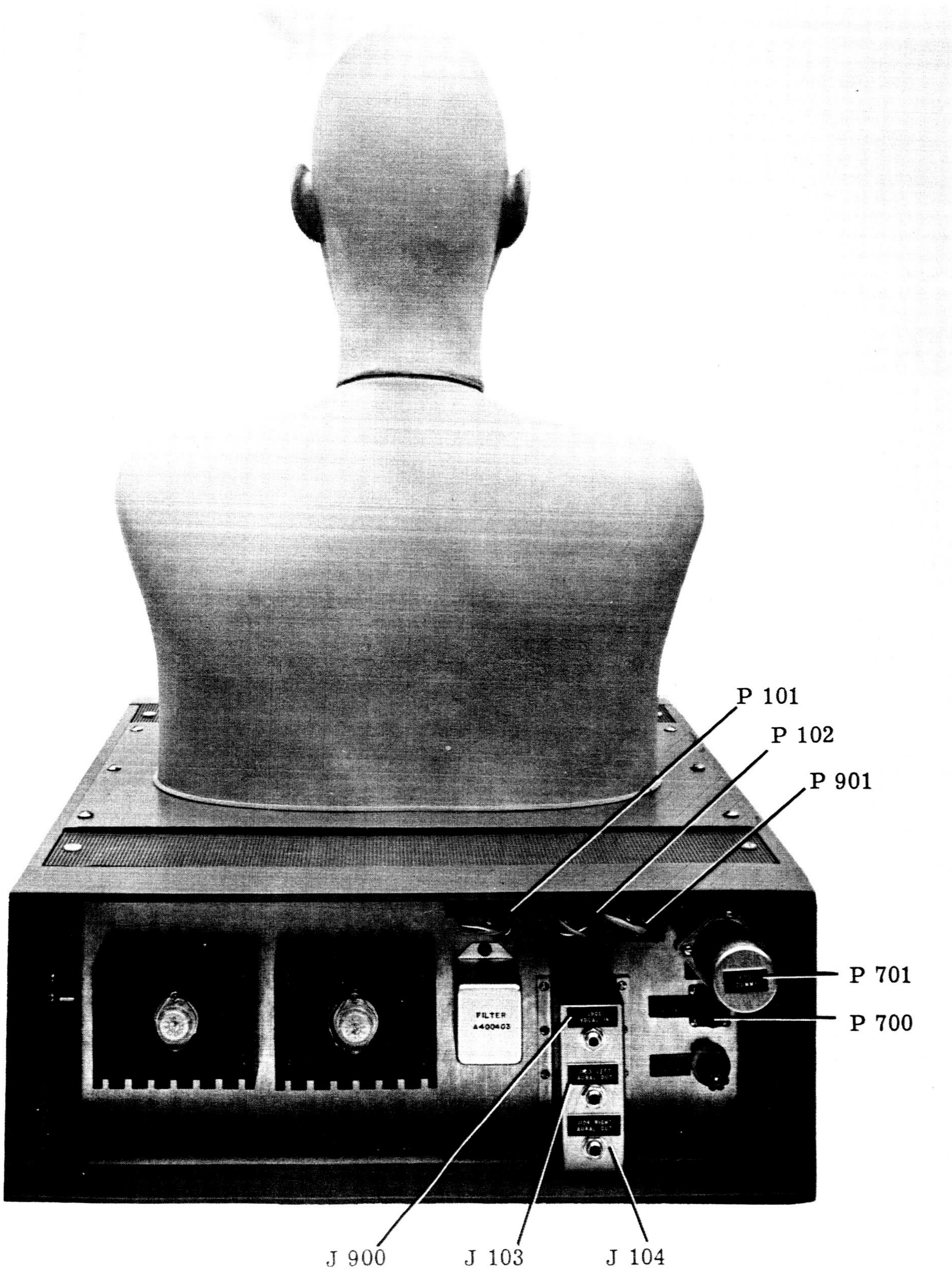


Figure 28a. ED Rear Panel

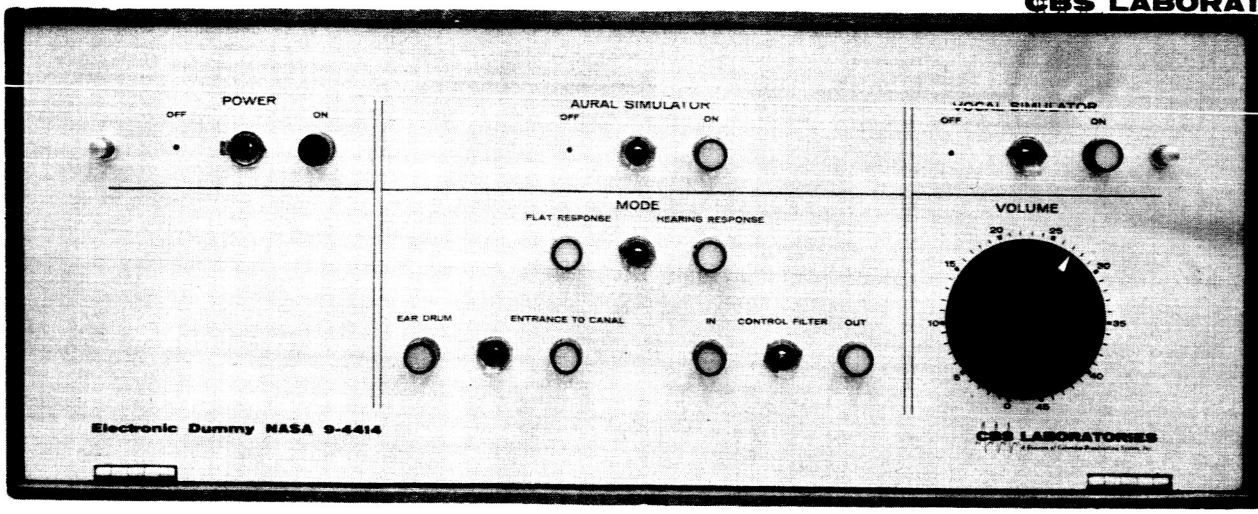


Figure 28b. ED Main Control Panel

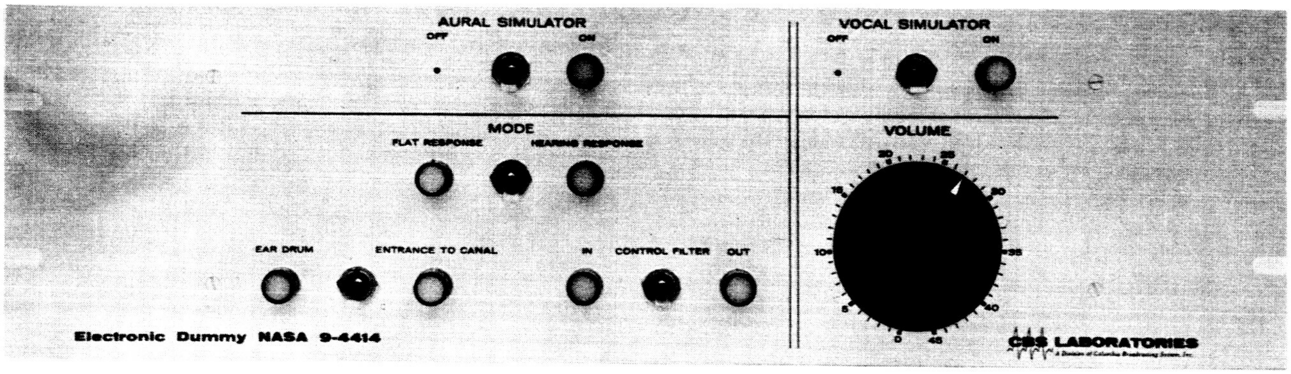


Figure 28c. ED Remote Panel

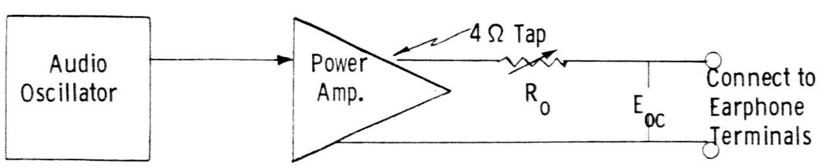


Figure 29. Test Setup Necessary to Drive Earphones During Calibration

2. Terminate J103 and J104 (left and right ear outputs, respectively) each with a 600-ohm load.

3. Plug the line cord into a 105-125 volt, AC, three-wire outlet.

Switch Functions (Figure 28b)

POWER	Introduces AC power into the unit.
AURAL SIMULATOR	Introduces DC for operating the Aural Simulator electronic circuitry and relays.
VOCAL SIMULATOR	Introduces DC for operating the Vocal Simulator electronic circuitry and relays.
FLAT RESPONSE MODE	Allows the ED to operate as a straight amplifier providing 2.2 volts peak-to-peak into 600 ohms for 95 db SPL at 1 kc.
HEARING RESPONSE MODE	Provides for loudness contour response as a function of input level. 2.2 volts peak-to-peak into 600 ohms are produced by 95 db SPL at 1 kc.
CONTROL FILTER	Applicable only in the Hearing Response Mode. Provides for a filter centered about 1 kc. This allows the function generators to select the proper operating contour by sampling the 1 kc level.
ENTRANCE TO CANAL	Introduces an equalizer into the signal path just ahead of the output amplifier to equalize for the resonance introduced by the ear canal. This effectively gives the SPL at the entrance to the canal.
EAR DRUM	Removes the equalizer from the signal path.
VOCAL SIMULATOR VOLUME	Volume control, a 600 ohm T-pad at the vocal amplifier input.

Remote Control

A remote control panel (Figure 28c) is provided with ED. This panel utilizes three-way switch action, expanding the versatility of the unit by enabling remote switching of all controls. The main AC power, however, can only be controlled at the main chassis. Indicator lights are used to show the condition of all functions.

Use of the remote control panel renders the Vocal Simulator Volume Control on the main chassis inoperative, eliminating the possibility of error due to having both attenuators in series.

TYPICAL MEASURING PROCEDURE

Helmet Attenuation

1. Place the ED in a random noise field and connect the output of one of the aural simulators into a 1/3-octave analyzer.

2. Attenuation may then be objectively measured as follows:

3. Set up the following functions on the ED: (a) AURAL SIMULATOR "ON", (b) FLAT RESPONSE MODE (c) ENTRANCE TO CANAL, (d) VOCAL SIMULATOR "OFF"

4. Obtain the 1/3-octave response of the aural simulator as a function of frequency in the noise.

5. Place the helmet over the head and obtain a second 1/3-octave response in the noise.

> CAUTION: Care should be taken in placing the helmet over the head of the ED. Do not twist the helmet severely as this may damage the flesh.

6. Attenuation of the helmet in question is obtained by taking the difference in db between the first and second response curves.

Calibration of Earphones

1. To determine the response of the earphone in question, place it over one of the aural simulators.

2. Drive the earphone as indicated in Figure 29.

3. Set R_o equal to the stated impedance of the earphones.

4. The earphones should be driven with a convenient "maximum power available" level* where power available is defined as:

$$W_A = \frac{E_{OC}^2}{4R_O} \qquad (1)$$

Where W_A = maximum power available

E_{OC} = open circuit voltage at amplifier terminals (earphone disconnected)

R_O = series resistance

A reference power of 1 milliwatt is typical for these measurements. The power level defines the value of E_{OC} since

$$E_{OC} = 2\sqrt{W_A R_O} \qquad (2)$$

Establish this open circuit voltage and connect the earphone.

5. Set the Aural Simulator in the FLAT RESPONSE MODE and either the EARDRUM or ENTRANCE TO CANAL position. The Entrance to Canal response will be that of a flat microphone while the eardrum response will include the canal resonance in the response.

6. Measure the output voltage of the ear microphone as a function of frequency. This output voltage may then be converted to sound pressure by the calibration curves in Figure 5a and b.

Microphone Near Voice Calibration

1. Set the Aural Simulator to OFF, Vocal Simulator to ON.

2. Connect an oscillator to the input of the vocal simulator and establish a convenient measuring level.

---

* Maximum Power available is a logical method to supply power from a resistive source to a resistive and reactive load.

3. Place the test microphone at its operational distance from the ED mouth. Obtain the response from 300 to 3000 Hz.

4. Remove this microphone and replace it with a calibrated microphone in the same position. The sound pressure at 1 kc should next be obtained. Since the vocal simulator is $\pm$ 2 db of the 1 Hz level in the 300 to 3000 Hz range, the 1 Hz value may be used and will give a calibration accuracy of $\pm$ 2 db. If greater accuracy is necessary, the sound field should be calibrated through the entire spectrum from 300 to 3000 Hz bandwidth. The calibration of the microphone under test is then obtained from the equation

$$S = \frac{E}{P} \tag{3}$$

where S = calibration of microphone

E = output of microphone, in volts

P = pressure of sound field, in dynes/cm^2 or, using decibel notation for all quantities, $20 \log S = 20 \log E - 20 \log P$

Other Measurements

The tests listed above are meant to be a guide, only, to the user of the ED, and do not describe all the measurements possible with this device. It may be used in binaural listening tests, loudness evaluations, and psychoacoustic tests, to mention a few. The procedures outlined above are also given as an aid in using the various functions of the ED and do not represent all of the methods by which tests may be made. The ED has been designed as a flexible measuring tool and the user should formulate test procedures based on the type of test that is to be performed and the parameters being evaluated.

CALIBRATION AND ALIGNMENT

Aural Simulator

For calibration and alignment of the Aural Simulator, the following test equipment is required:

Audio Oscillator 600 ohm output impedance (H-P 200 CD or equiv.)

AC Vacuum Tube Voltmeter (Ballantine 310 A or equiv.)

Distortion Analyzer (H-P 330 B or equiv.)

DC Voltmeter (Simpson Model 270 or equiv. or standard DC VTVM)

DC Power Supply (H-P 6200A or equiv.)

Electronic Dummy Extension Boards

Preamplifier Simulator

Position the Electronic Dummy control switches as follows:

POWER:	"ON"
AURAL SIMULATOR:	"ON"
MODE:	"HEARING RESPONSE"
EARDRUM/ENTRANCE TO CANAL:	"ENTRANCE TO CANAL"
CONTROL FILTER:	"OUT"
VOCAL SIMULATOR:	"OFF"

Left and right ear calibration are the same. It will be easier to complete each section of the calibration procedure for both ears before proceeding to the next step. Left and right component designation, board numbers, etc. are given together with a slash bar, the left ear shown first. (For example, R81/R381 means R81 pertains to the left ear and R381 pertains to the right ear.)

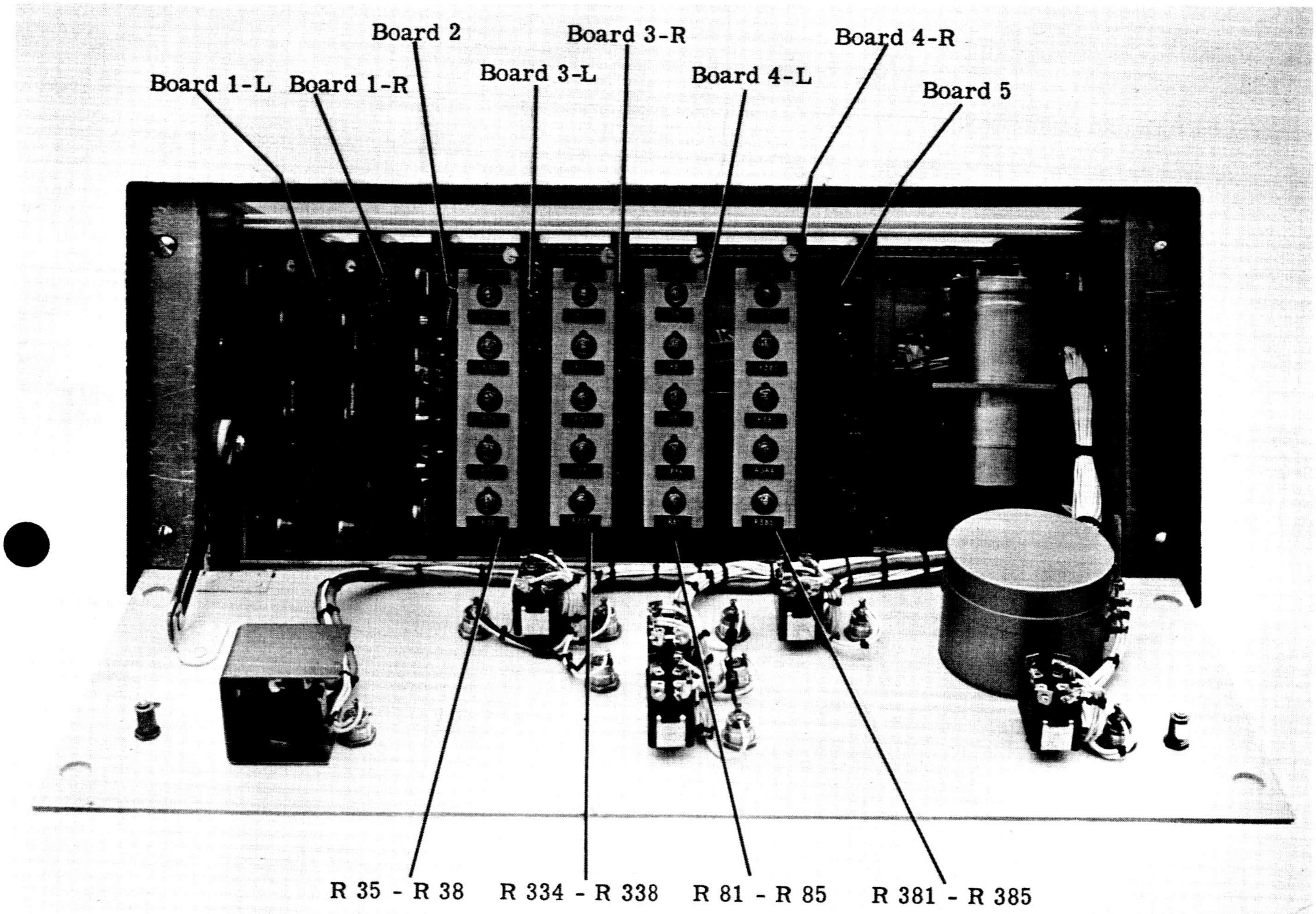


Figure 30. Electronics Package, Front View, Showing Circuit Boards in Place

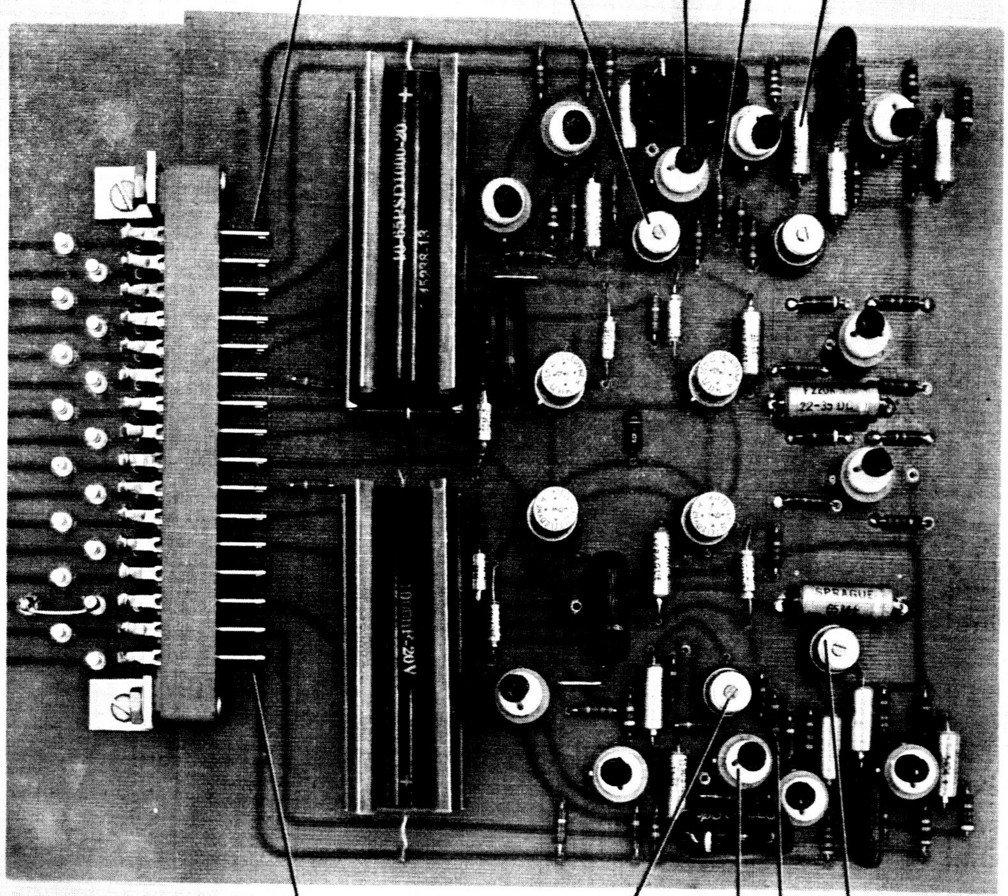
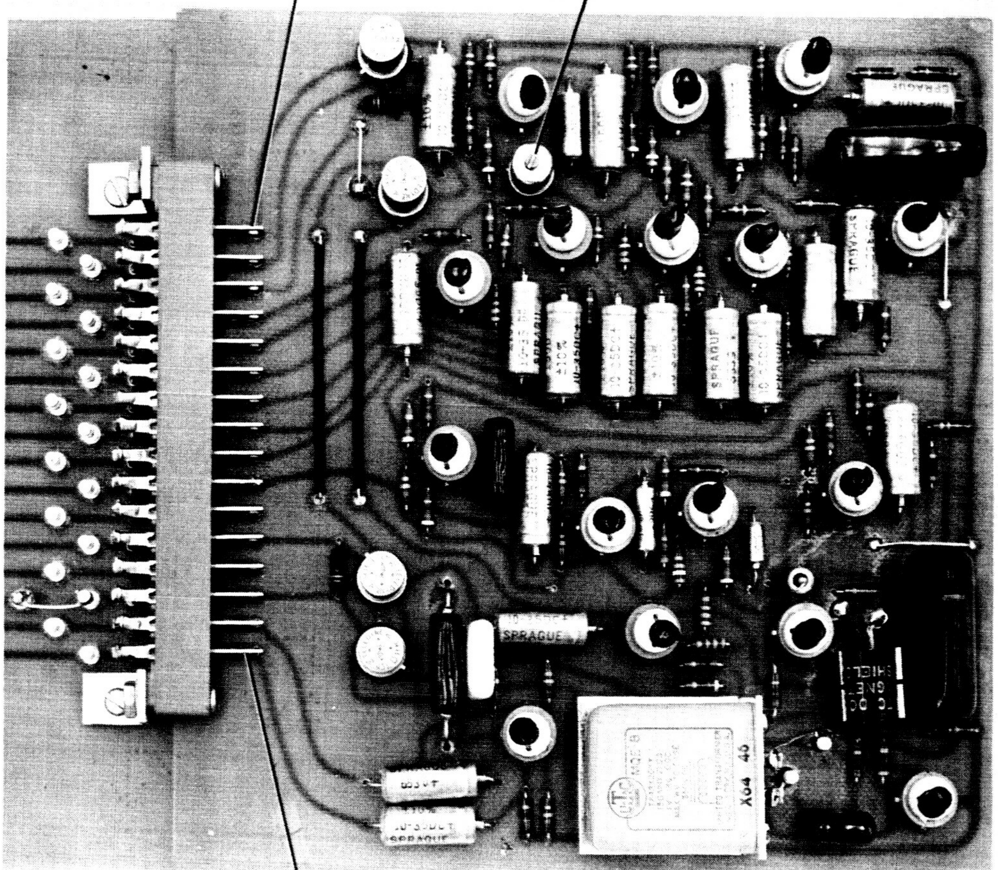


Figure 31. Circuit Board # 2

Pin # 16

R 166 / R 415



Pin # 1

Figure 32. Circuit Board # 1
(One Used Per Channel)

Ear Amplifier Calibration

1. Disconnect plugs P101/P102 on the back panel (See Figure 28a).

2. Connect the Preamplfier simulator to J101/J102.

3. Locate on extension test board and make sure that a jumper exists between test points A and B on the board. Remove Electronic Dummy board 2 (See Figure 30). Insert the test board in place of board 2. Insert board 2 in the end of the test board.

4. Feed the Preamplifier simulator from an audio oscillator. Adjust the oscillator audio output to 0.63 volts RMS. The attenuator will terminate the audio oscillation in 600 ohms.

5. Place an AC VTVM between pin #13/#5 and ground. Adjust R64/R364 for a reading of 0.10 volts RMS as measured by the VTVM.

6. Remove the AC VTVM from pin #13/#5 of the test board and place it between the emitter of Q5/Q305 and ground (See Figure 31).

7. Using a 600 Decade Attenuator or equivalent, reduce the output of the audio oscillator by 50 db.

8. Adjust R15/R315 for a reading 0.08 volts rms as measured by the VTVM.

Flat Mode Calibration

1. Terminate the output of the Electronic Dummy Aural Simulator (J103/J104) (See Figure 28a) with a 600-ohm 1-watt resistor.

2. Place an AC VTVM across the 600 ohm load.

3. Place the Mode switch in the HEARING RESPONSE MODE.

4. Feed the Preamp Dummy Plug-Attenuator with a 1 kc signal sufficient to give approximately 1 volt out of the Aural Simulator.

5. Record the output reading.

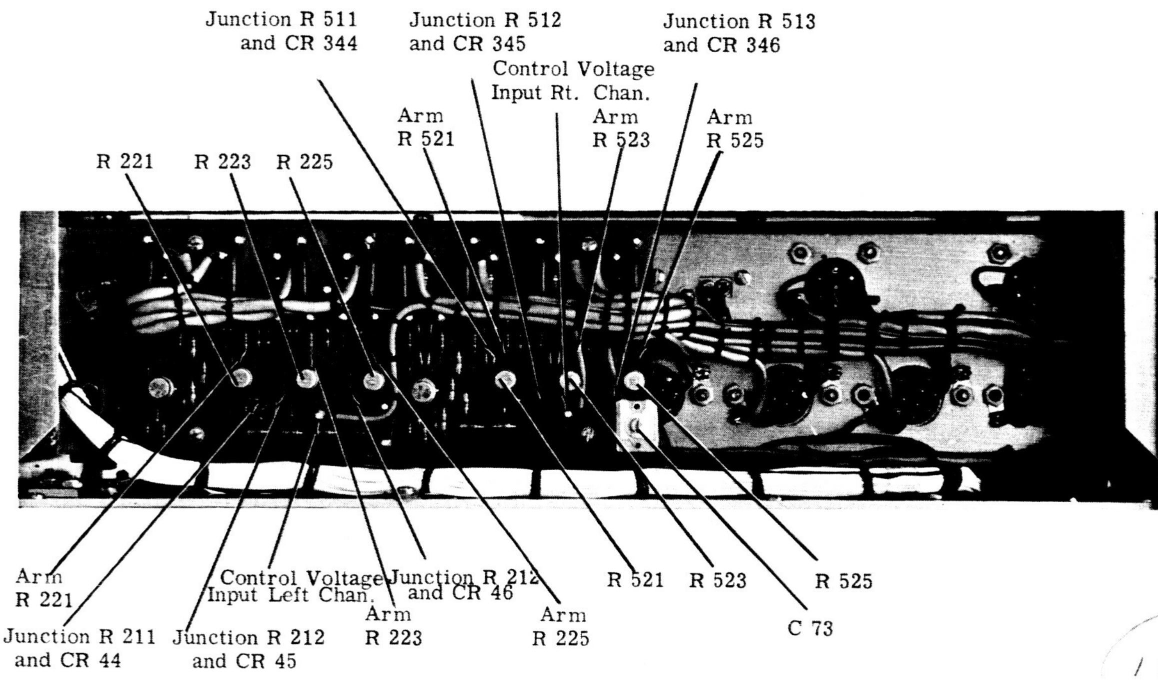


Figure 33. Low Frequency Attenuator Circuitry (Board #C400332)

6. Place the Mode switch in the FLAT RESPONSE MODE, adjust R166/R415 to give the same meter reading as above (see Figure 32.)

7. Return the Mode switch to the HEARING RESPONSE POSITION.

Zener Break-Points

1. Remove the jumper between test points A and B on an extension test board.

2. Replace Electronic Dummy board #3 L/3R with the test board.

3. Feed test point B on the test board with +2.10 volts DC from a low impedance voltage source. (Connect an accurate DC voltmeter as follows: positive lead to the junction of R211/R511 and CR 44/CR344, negative lead to the arm (Terminal #2) of R221/R521).

4. Adjust R221/R521 for a reading of 0.50 volts on the meter (see Figure 33).

5. Feed test point B on the test Board with +2.90 volts DC. (Connect the positive lead of the voltmeter to the junction of R212/R512 and CR 45/CR345; the negative lead to the arm (Terminal #2) of R223/R523).

6. Adjust R223/R523 for a reading of 0.50 volts on the meter (see Figure 17).

7. Feed test point B on the test board with +7.00 volts DC. (Connect the positive lead of the voltmeter to the junction of R213/R513 and CR 46/CR346; the negative lead to the arm (terminal #2) of R225/R525.)

8. Adjust R225/525 for a reading of 0.50 volts on the meter (see Figure 33).

Output Stage DC Balance

1. With the MODE switch in the FLAT RESPONSE position apply a

R 118

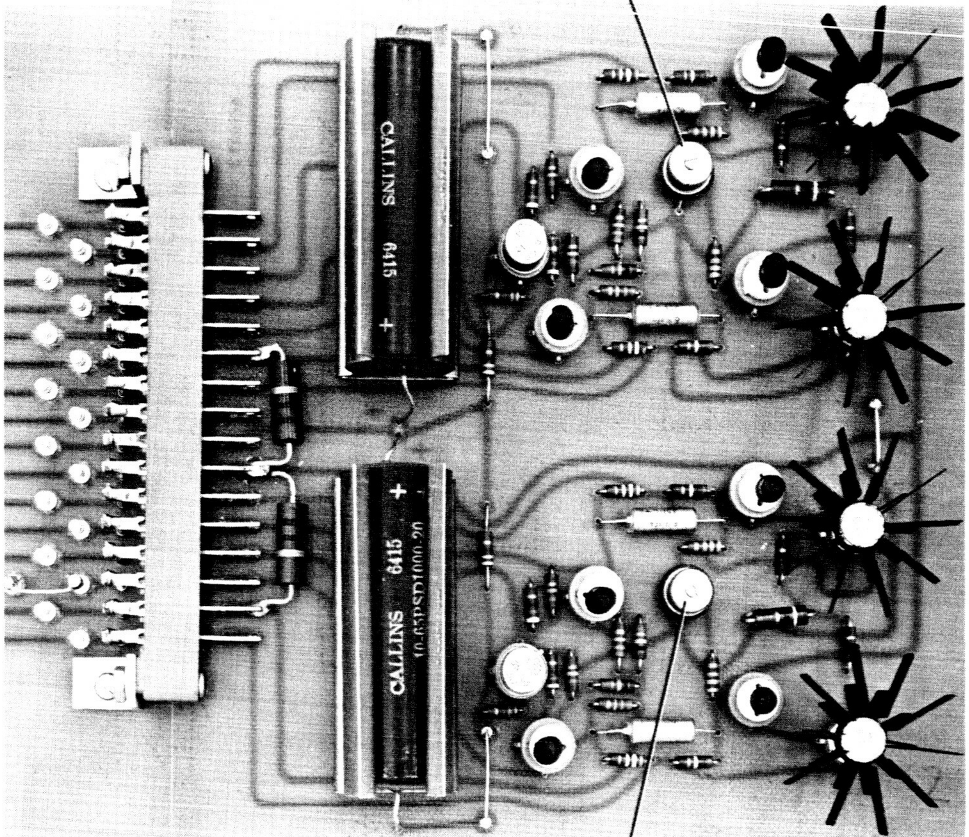


Figure 34. Aural Simulator Output Amplifiers (Board # 5)

R 418

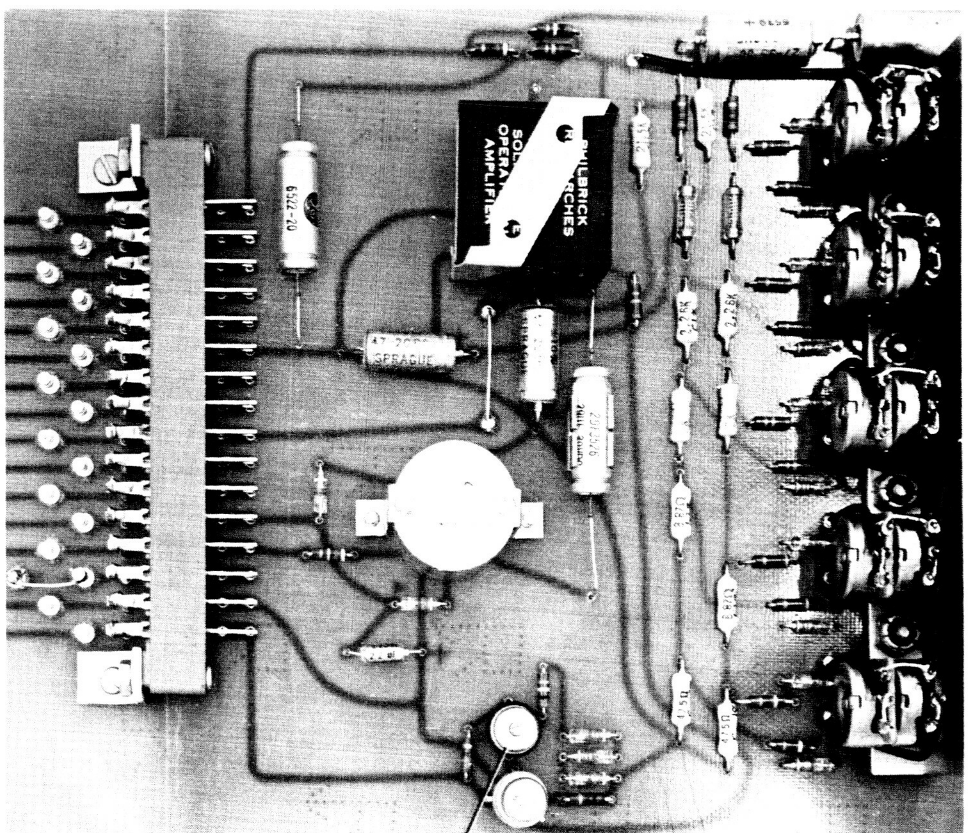


Figure 35. Dummy Board # 3 (One Used per Channel)

R 109 / R 409

50 cps sine wave signal to the ear input jack (J101/J401) located at the rear of the unit using the pre-amp dummy plug. Adjust the level to provide 0.1 volts RMS as read on an AC VTVM at pin #13/#5 of board #2. Use an extension test board to make these pins accessible.

2. With a distortion measuring instrument such as the Hewlett Packard Model 330 B Distortion Analyzer connected across the amplifier output (J103-J104), and with the amplifier output loaded with 600 ohms, adjust R188/R488 for minimum distortion. (See Figure 34).

3. Do not remove the output amplifier board from the unit, but remove the four function generator boards. This will render R188/R488 accessible to a small screwdriver.

4. Return the Mode switch to the HEARING RESPONSE position.

Right Channel Noise Balance

1. Refer to Figures 28a and 33. Remove plug P102 from the back panel.
2. Terminate the output of the right channel (J104) in 600 ohms.
3. Place an AC VTVM across the termination.
4. Adjust C73 for minimum noise as read on the voltmeter.

Function Generator Calibrator

1. Using the Pre-amplifier Dummy Plug - Attenuator, feed J101/J102 with a 0.63 volt RMS 1 kc signal.

2. Using an extension test board (making sure a jumper exists between test points A and B), remove board 3L/3R and reinsert it in the circuit on the test board.

3. Adjust R109/R409 (see Figure 35) for zero volts DC at the control voltage input of board C400332 (see Figure 33). The Aural

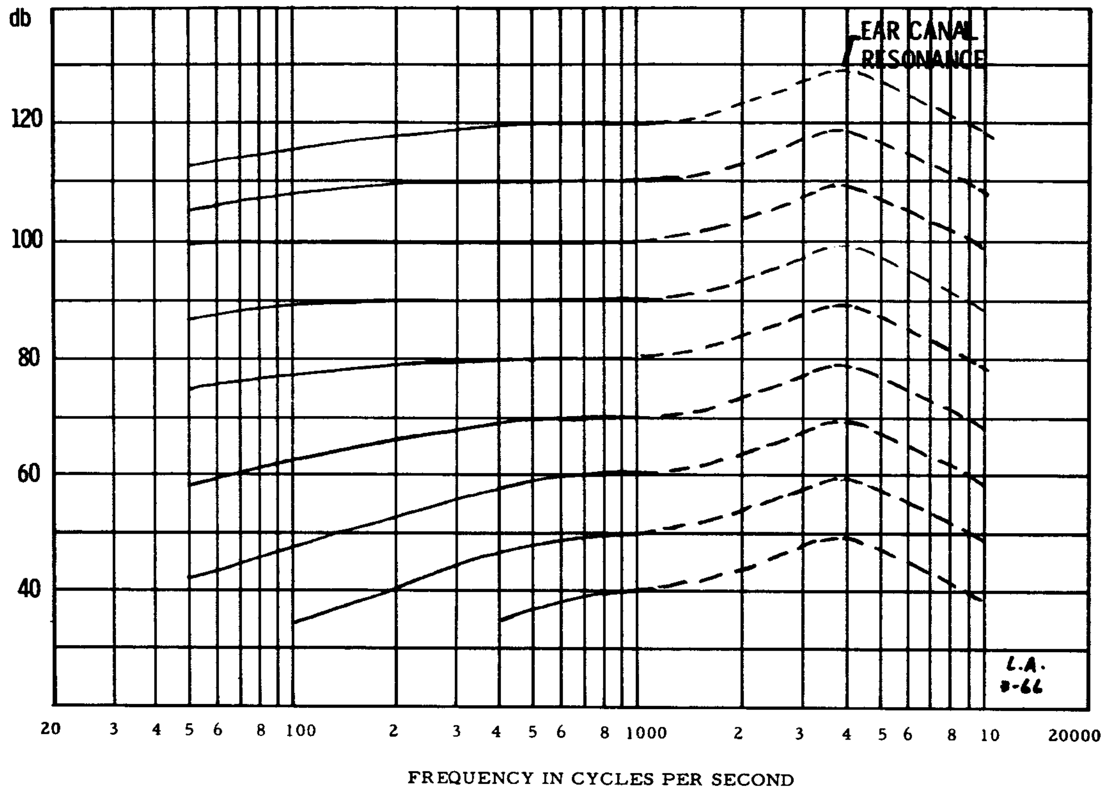


Figure 36. Hearing Response

Simulator is now calibrated. By feeding 6.3 volts RMS through a 600-ohm decade attenuator into the pre-amp Dummy Plug-Attenuator and into J101/J102, the hearing response curves (Figure 36) should be duplicated ± 3 db.

4. Should the unit fail to produce these within given tolerence, recheck all the steps of the calibration procedure.

5. If the unit still does not reproduce the hearing response curves accurately, feed a 1 kc tone using the set up described above.

A 6.3 volt input represents the 120 db level. Ten 10-db steps will give the full signal range of the unit. Using a DC voltmeter between the control voltage input and ground on board C-400332, the control voltages can be measured and should coincide (within 0.2 volts) with the following:

120 db	1.30 volts
110 db	0.58 volts
100 db	0 volts
90 db	0.40 volts
80 db	0.60 volts
70 db	1.10 volts
60 db	2.30 volts
50 db	2.80 volts
40 db	4.10 volts

Potentiometers R34 to R38 and R81 to R85 (see Figure 30) should be used to adjust the voltages, although these voltages are not critical.

6. Next, potentiometers R221/R521, R223/R523 and R225/R525 should be adjusted. Starting at the 90 db level adjust R221/R521, then successively reduce the level in 10-db steps. There is considerable interaction between these settings.

7. Find the best settings of all the potentiometers that gives the proper attenuation. The proper attenuation should be arrived at by comparing the 1 kc with the 70 cps level at each level. From the differential hearing response curves, the correct attenuation for each

level is as follows:

Level (SPL)	Attenuation (db)
120	5
110	2
100	6
90	2
80	4
70	9
60	15
50	21
40	27
30	32
20	37

8. This completes the Aural Simulator Calibration.

Vocal Simulator Calibration

With exception of the attenuator, C905, Q904, Q905, Speaker Equalization Filter (#400403), and the speaker protective circuitry, all components of the vocal simulator are mounted on a single card in the rear of the unit. The output transistors are mounted on heat sinks and together with the filter are attached to the rear flange. The speaker protective circuitry is mounted at the speaker terminals.

Service and calibration of the unit is straightforward. Should a transistor require replacement, only two adjustments are required. The procedure is outlined on the following page:

1. Disconnect speaker and replace with a 16-ohm 25-watt resistor as a dummy load.

2. Connect an oscilloscope, AC VTVM, and distortion analyzer to the output.

3. Connect a precision DC voltmeter between the positive terminal of C 905 and ground. The positive lead of the voltmeter is connected to the capacitor. The voltmeter should be capable of reading to 60 volts.

4. Clip an accurate current probe, e.g. HP 428B, around the collector, (Blue) lead of Q904 or Q905. The range should be 100 ma.

5. Turn R910 and R912 fully counterclockwise.

6. Energize the amplifier. There should be no current indicated by the current probe.

7. Adjust R 912 until the DC voltmeter reads 29.5 volts.

8. Adjust R910 until the current meter indicates 75 ma.

9. Repeat (7) and (8) .

10. Allow the amplifier to warm up for 15 minutes.

11. Repeat (7) and (8). The operating point of the amplifier has been set.

To check gain, frequency response and distortion proceed with the following steps:

1. Connect a low distortion audio oscillator to the vocal simulator input.

2. Adjust input level to 0.78 volts rms at 1 KHz.

3. Output voltage should be within 2 db of 5.65 volts rms.

4. Frequency response should be flat +0 db, -0.5 db from 300 Hz to 3 KHz.

5. Total harmonic distortion at the 10 watt level (12.6 volts rms output) should be less than 0.25% from 300 Hz to 3000 Hz after corrections are made for generator distortion.

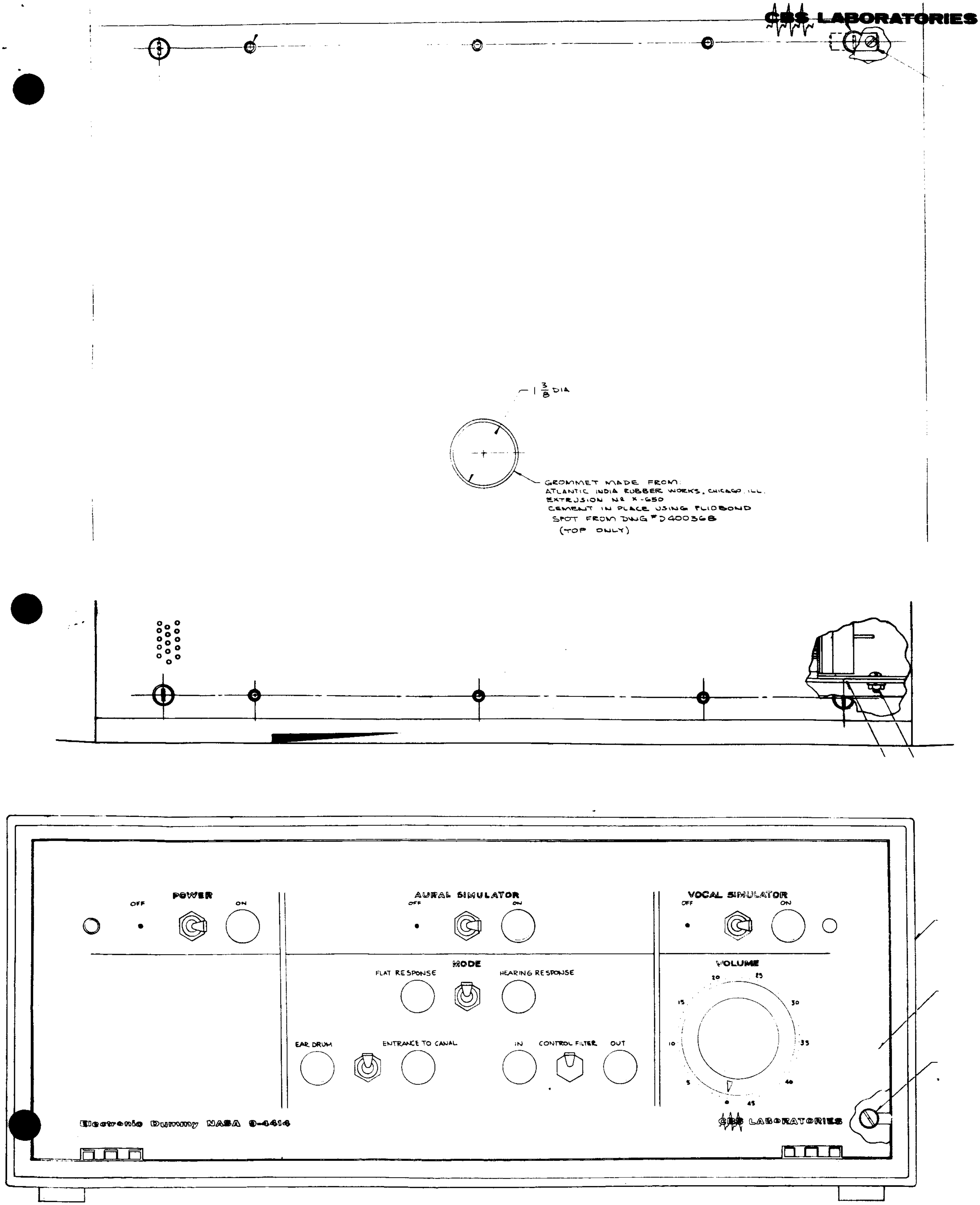


Figure 37. Electronic Unit Final Assembly

DISASSEMBLY AND REASSEMBLY OF TORSO AND HEAD

Disassembly

Should it become necessary to gain access to an interior component, instructions for disassembly and reassembly are as follows:

Removing the Torso from the Electronic Package (See Figures 37 and 38)

1. Turn off the main power switch on the front panel and remove plugs J101, J102, & J901 from the rear of the electronic chassis.

2. Loosen the four screws in the perforated grill and remove the six Fillister head screws from the torso base plate.

3. Move torso forward about five inches on the electronic base and free the three electrical cables from the chassis.

4. Remove the torso and perforated grill from the electronics sections and then separate the torso from the grill.

5. Remove the eight flat head screws from the bottom of the torso and take off the base plate.

Separating the Head from the Torso (See Figure 38)

1. There are three Fillister head screws located in the neck of the ED under the flesh. Lift the flesh and remove these screws.

2. Place the torso and head face down on a table. Loosen the two thumb screws and the Allen head set screw on the inside of the torso.

3. Separate the head and torso at the neck.

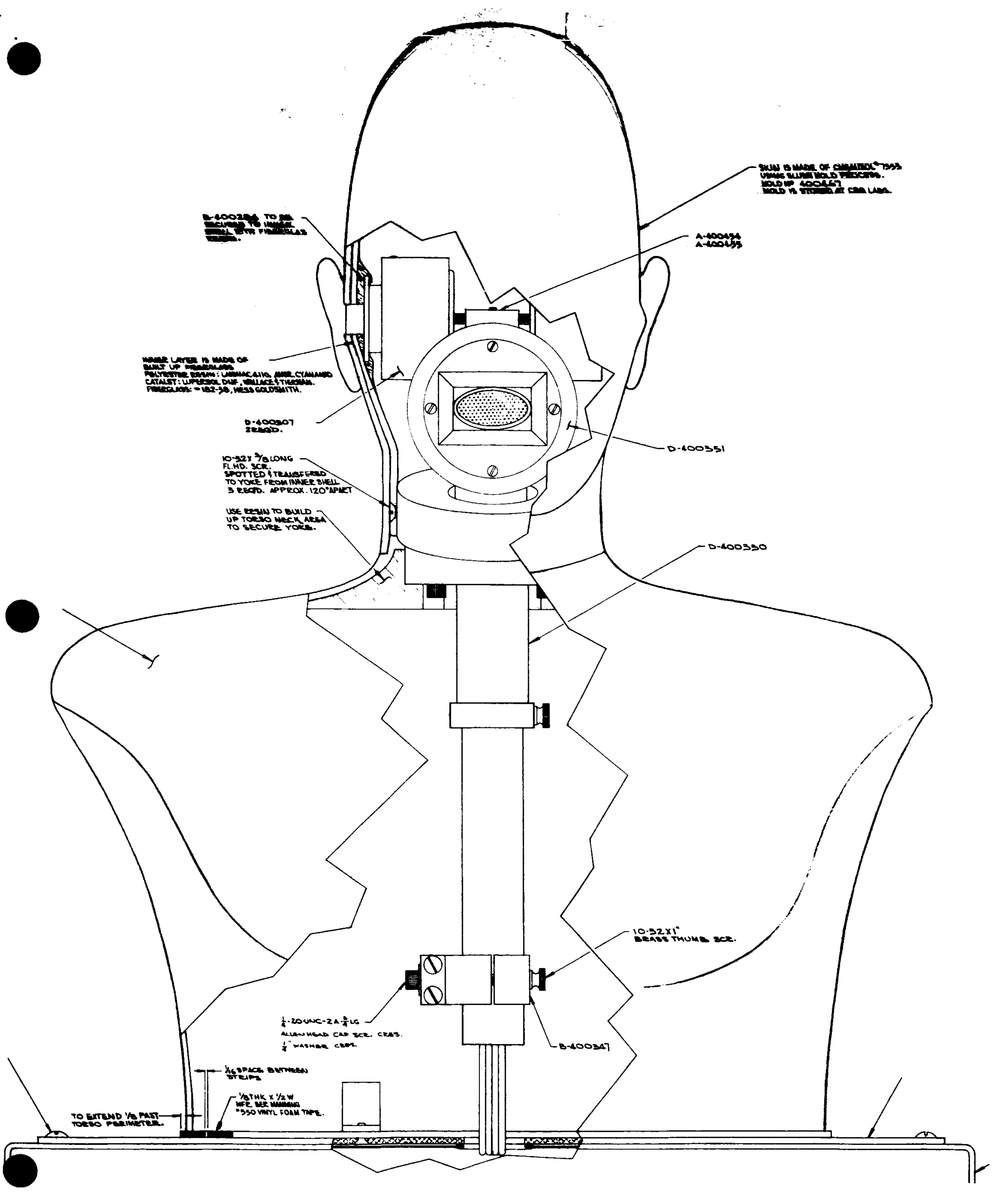
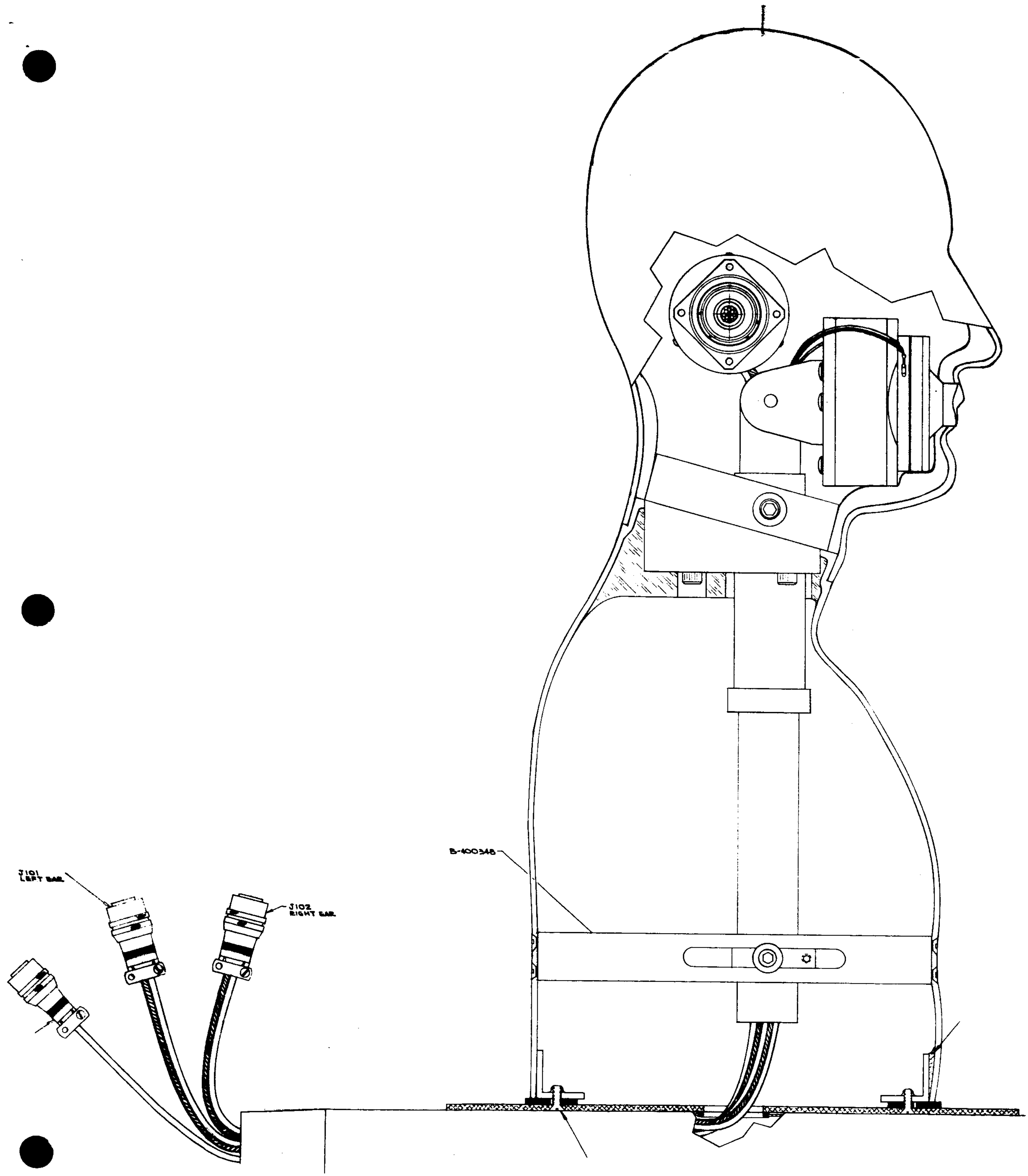


Figure 38. Electronic Dummy Final Assembly


B-400348
J101
LEFT EAR
J102
RIGHT EAR

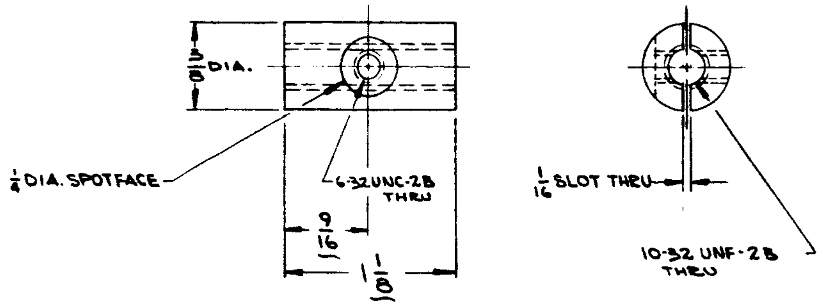


Figure 39a. Ear Canal Coupler Clamping Bar

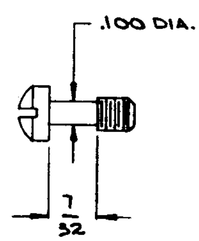


Figure 39b. Ear Canal Coupler Captive Screw

Removing the Vocal Simulator from the Head (See Figure 38)

1. A piece of foam cushions the vocal simulator in place. Remove this foam and rotate the speaker 90° so that the mouth of the speaker is facing the top of the head.

2. Carefully slide the speaker out through the neck opening.

Removing the Aural Simulators (See Figure 38)

1. A suspension bracket (see Figure 39) connects the two ear canals. Loosen the screw in this bracket and it will separate into two halves which may then be removed.

2. Next, remove the left ear canal by turning the outer locking ring (see Figure 40) 1/2 turn counter-clockwise and sliding it out of the neck.

3. Repeat with the right ear.

Disassembling the Vocal Simulator (See Figure 41)

1. Remove four flat head screws holding the coupler to the speaker.

2. Remove two binding head screws connecting the speaker to the speaker post.

Disassembling the Aural Simulator (See Figure 40)

1. Grasp the ear canal in one hand and the preamplifier can in the other hand. Separate these pieces by unscrewing the canal from the preamplifier.

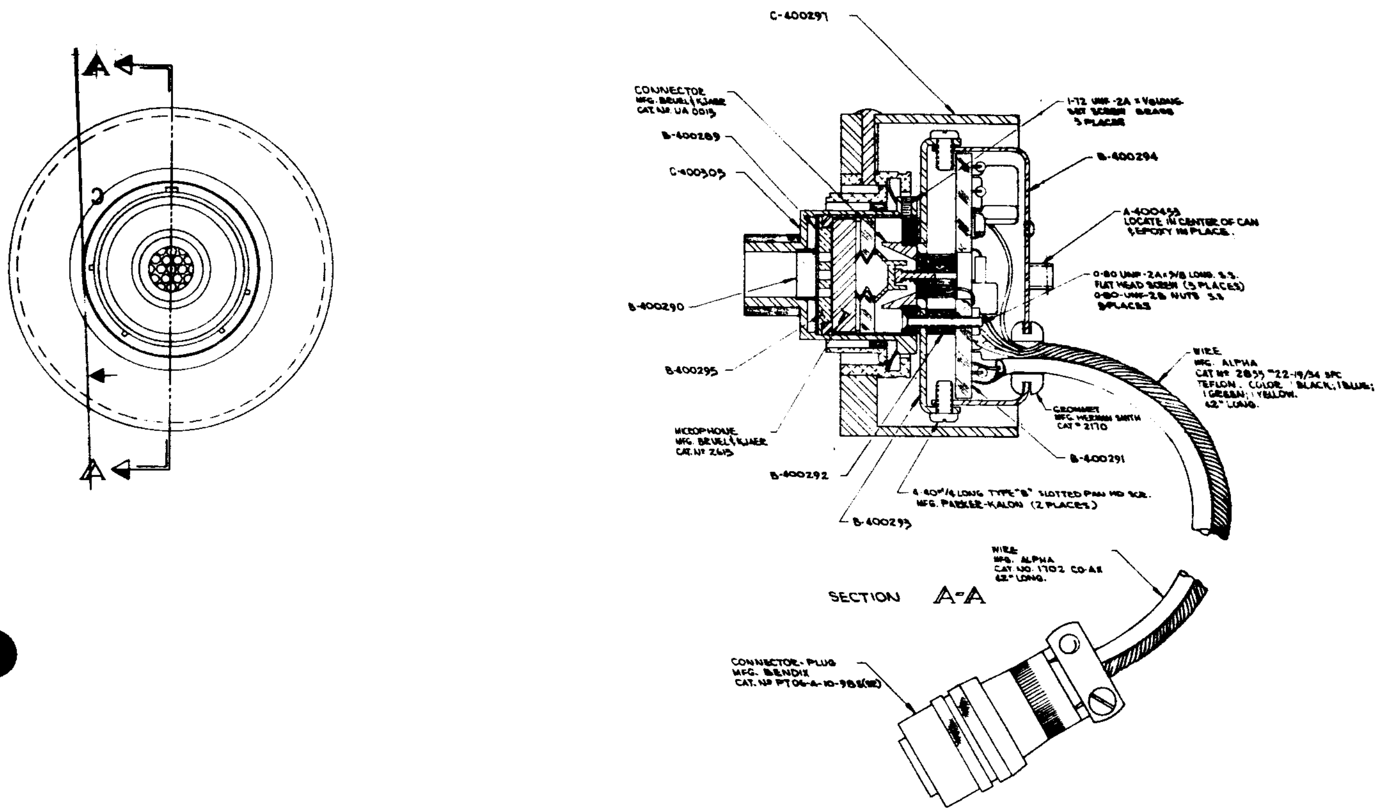


Figure 40. Ear Canal Microphone Assembly

2. Remove the microphone by loosening three set screws in the ear canal. (see Figure 42)

Reassembly

Assembling the Vocal Simulator (See Figure 41)

Connect the coupler and suspension bar to the speaker. Use the four flat head screws for the coupler and the two Fillister head screws for the suspension bar.

Assembling the Aural Simulator (See Figure 40)

Insert the microphone into the ear canal, and lock it in place with the set screws provided.

> NOTE: There is a pressure equalization hole on the side of the microphone and a similar hole on the inside of the ear canal (see Figure 43). Make sure that these holes are in line when the microphone has been inserted into the the canal. Next, place the preamplifier inside the locking ring and screw the ear canal into the connector on the electronic can.

Inserting the Aural Simulators Into the Head (See Figure 38)

1. Insert the right ear canal into the mounting bracket provided in the head.

2. Turn the locking ring clockwise until it locks in place (1/2 turn).

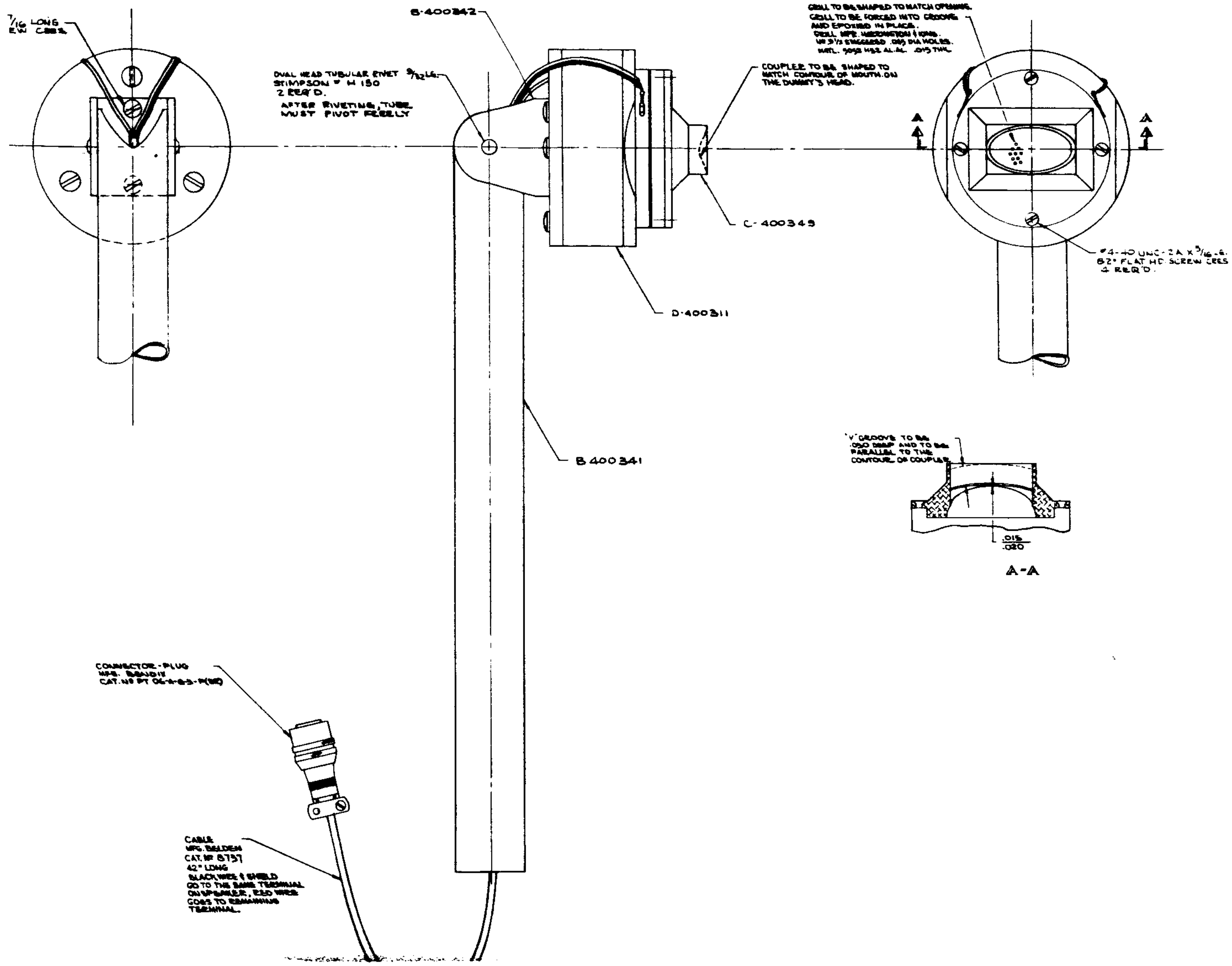


Figure 41. Speaker (Voice) Pivot Sub-Assembly

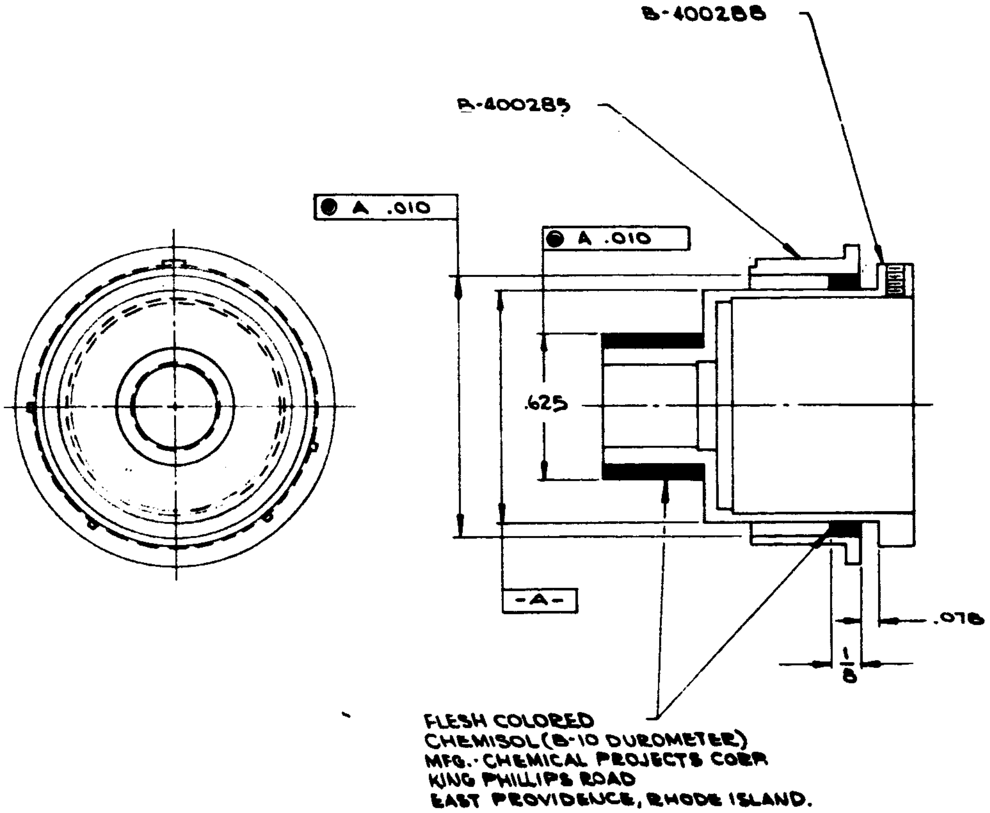


Figure 42. Ear Canal Microphone Housing Sub-Assembly

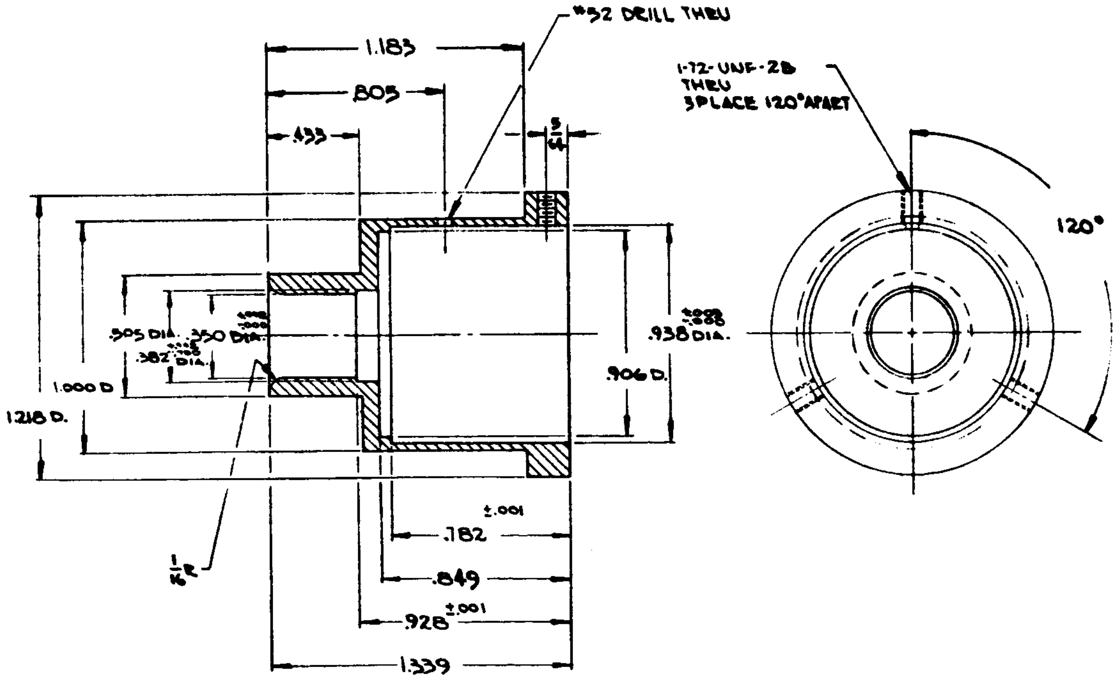


Figure 43. Ear Canal Microphone Housing

3. Repeat procedure with the left ear.

4. Place the suspension bracket halves over the studs on the ear canal and lock in place by tightening the screw in the bracket. (See Figure 39)

Inserting Vocal Simulator into Head

1. Push the electrical cables from the two aural simulators and the vocal simulators through the speaker bar of the vocal simulator.

2. Slide the speaker into the head carefully and rotate it 90° so that the coupler is aligned with the mouth opening in the head.

3. Place the piece of foam that has been provided between the back of the speaker and the head. This foam holds the speaker in place during the remainder of the assembly procedure.

Connecting the Head to the Torso (See Figure 38)

Note: It is recommended that two persons perform this task.

1. Place the head and torso face downward on a flat table.

2. Feed the three electrical cables through the pivot sleeve in the torso yoke and the locking block on the support bar at the base of the torso.

3. Slide the speaker through the neck of the torso and slowly move the two sections together. When the speaker support bar has been pushed through far enough, slide it through the locking bracket at the base of the torso.

4. Join the head to the torso by gently pushing the two parts together.

NOTE: There are three holes on the neck of the artificial head (under the flesh) which should align with the holes on the torso yoke when the two pieces are joined.

5. Secure the head by locking the two thumb screws and the Allen head screw.

6. Three flat head screws are then inserted in the neck holes to complete the assembly.

Connecting the Torso to the Electronic Package (See Figure 37 and 38)

1. Connect the torso to its base plate by means of eight flat head screws. Make sure the electrical cables pass through the hole in the center of this plate.

2. Place the perforated grill on to the electronic base and allow it to overhang at the front edge by about 5 inches. Sit the torso and base on top of this grill making sure that the electrical cables pass through the grommeted hole.

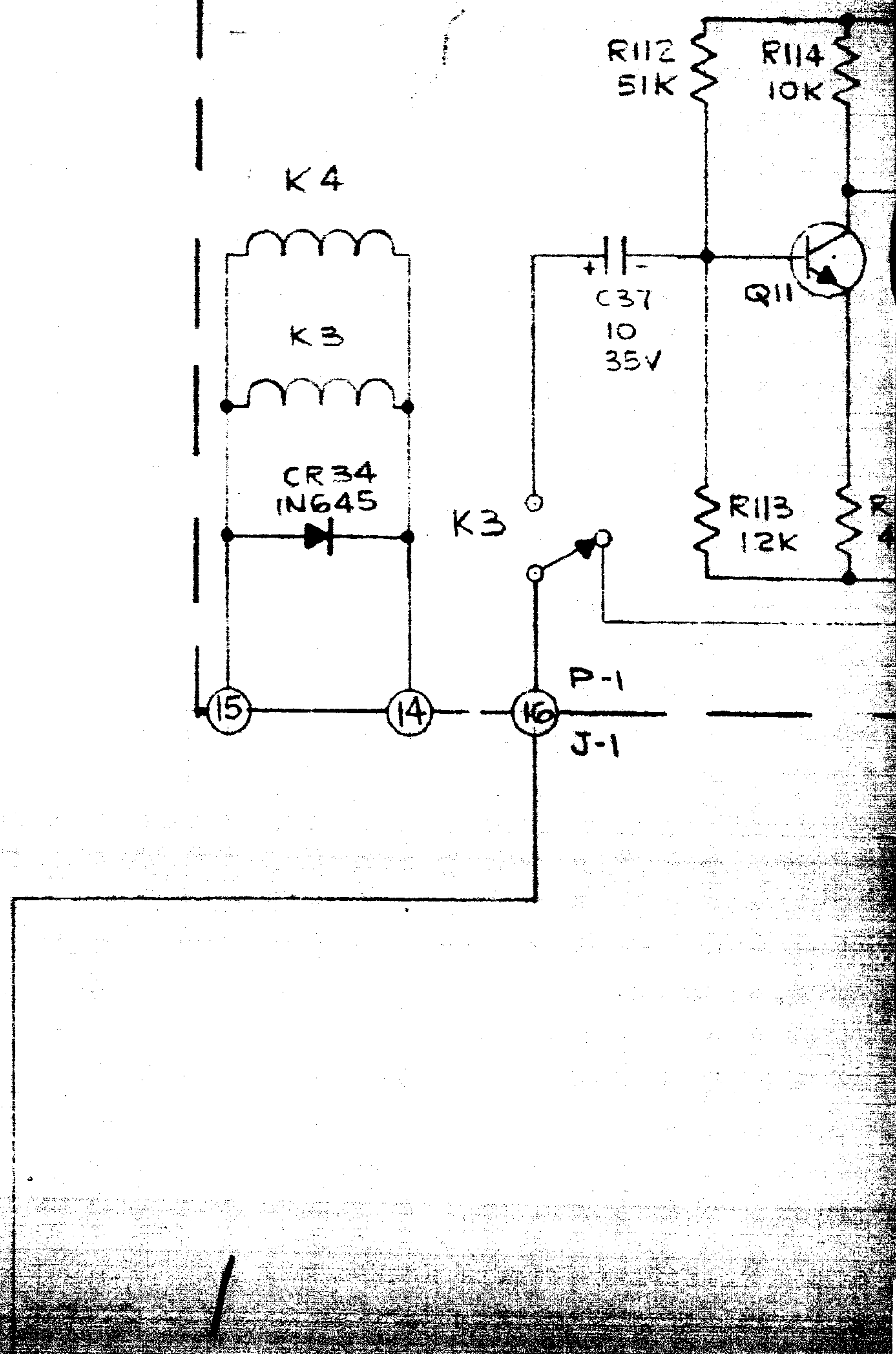
3. Pass the three electrical connectors to the rear of the chassis and connect them in their appropriate positions. (J101, J102, J901)

4. Slide the perforated grill into its proper position on the electronic chassis, and lock it in place by turning the lock screw at the corners of grill 1/2 turn. Secure the torso to the electronic base with the six flat head screws provided.

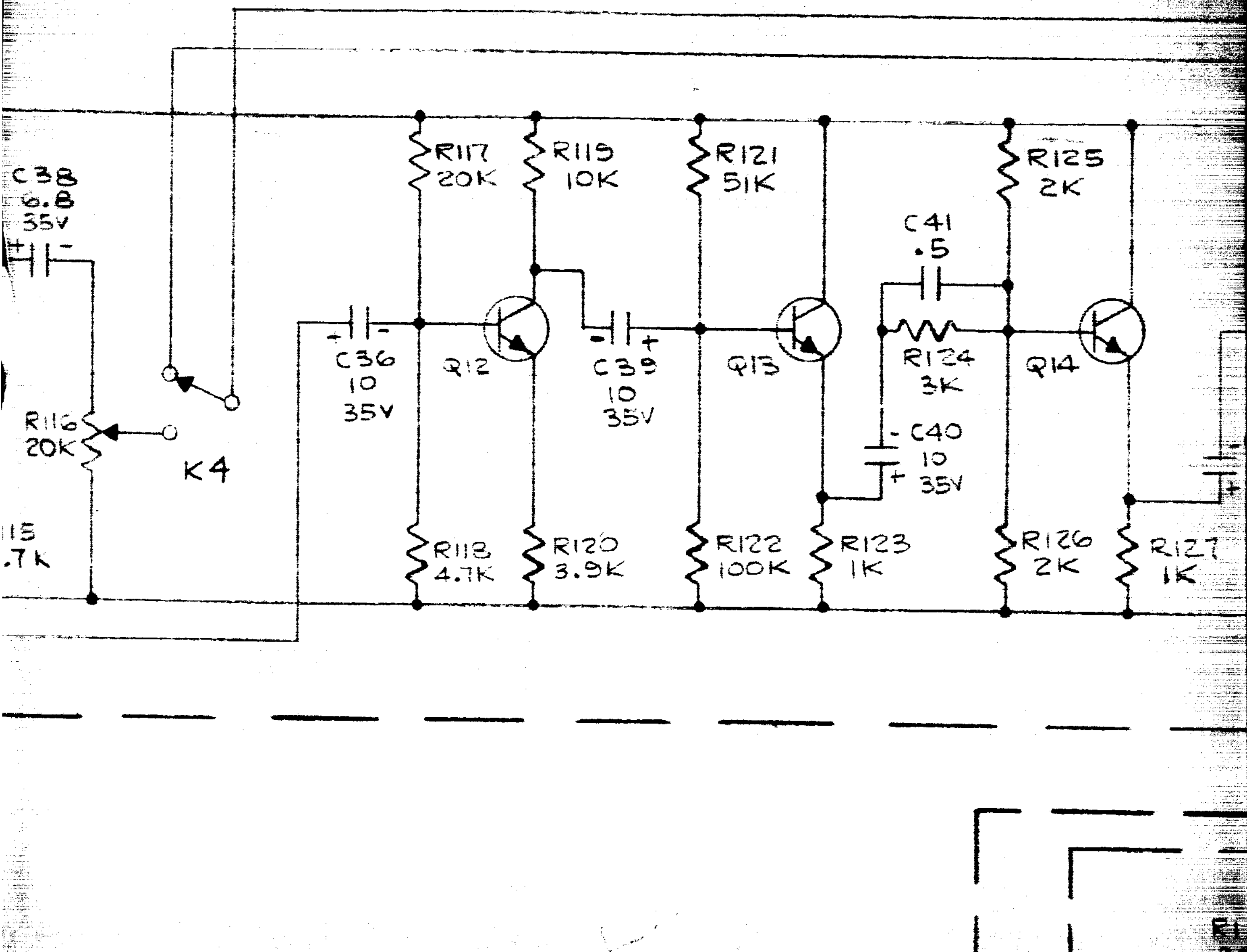
5. This completes the reassembly procedure.

10

C 400325 LEFT



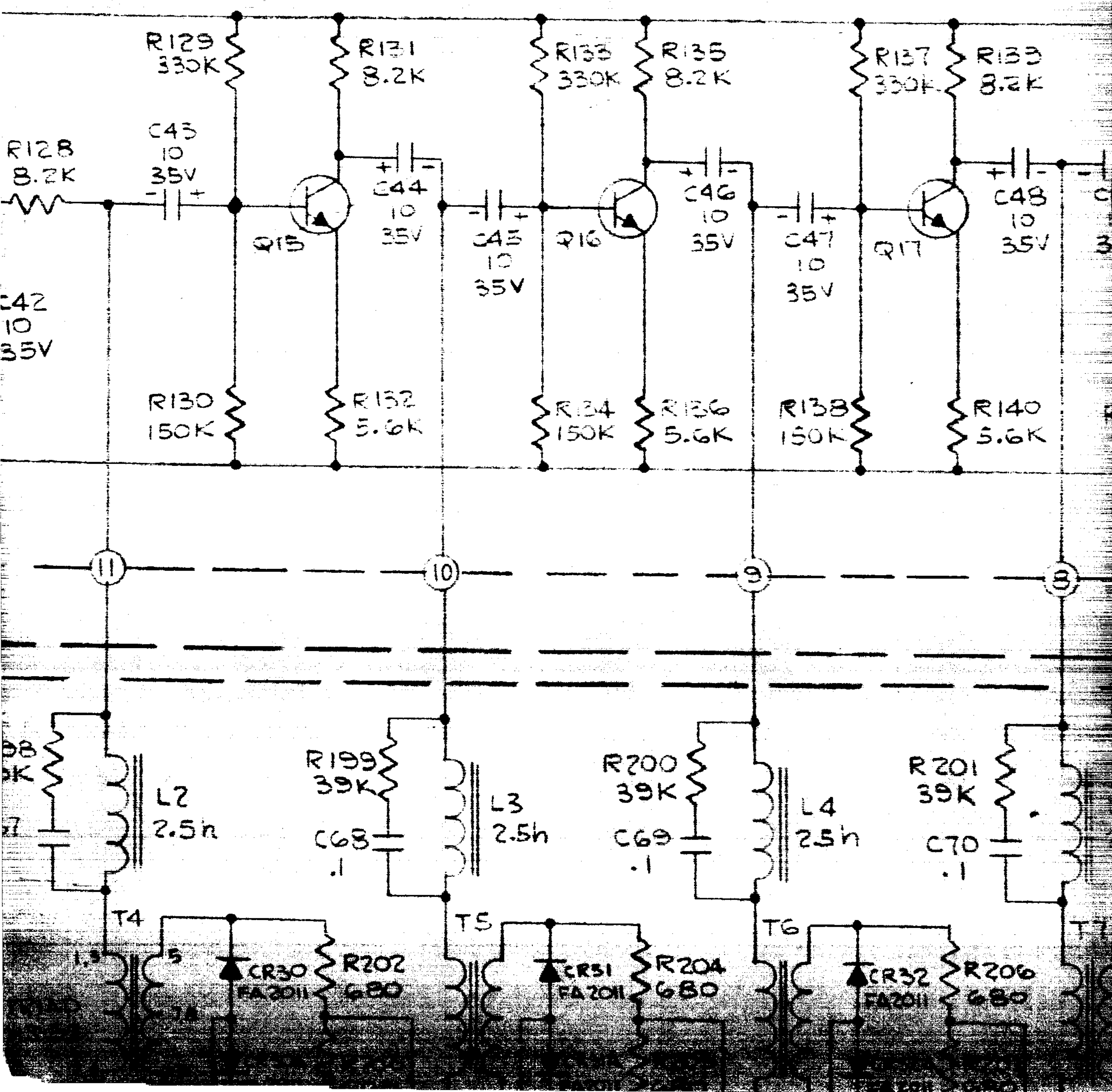
1


C38
6.8
35V
R116
20K
K4
R115
4.7K
R117
20K
R118
4.7K
C36
10
35V
Q12
R119
10K
R120
3.9K
C39
10
35V
R121
51K
R122
100K
Q13
R123
1K
C41
.5
R124
3K
C40
10
35V
R125
2K
R126
2K
Q14
R127
1K

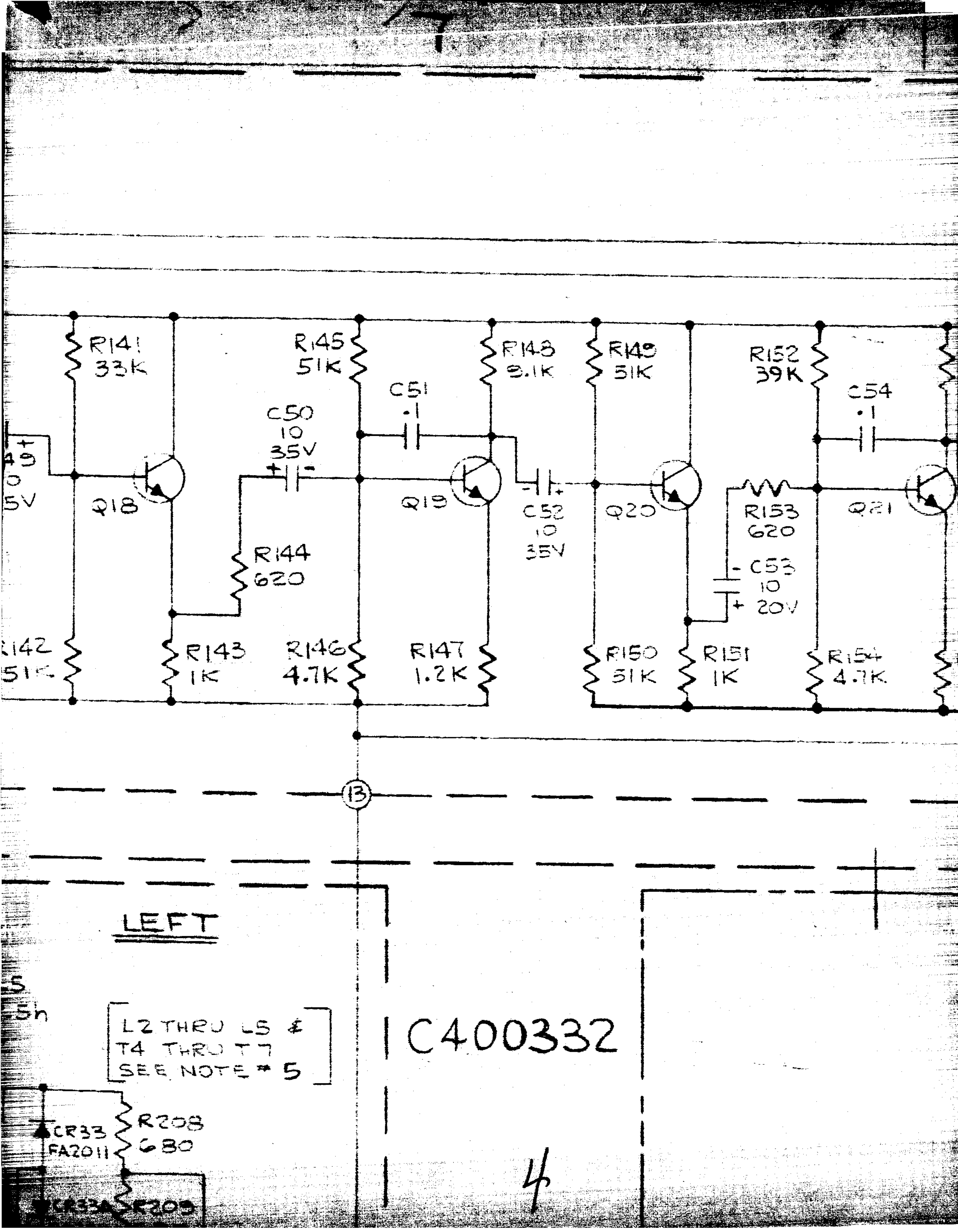
2

8

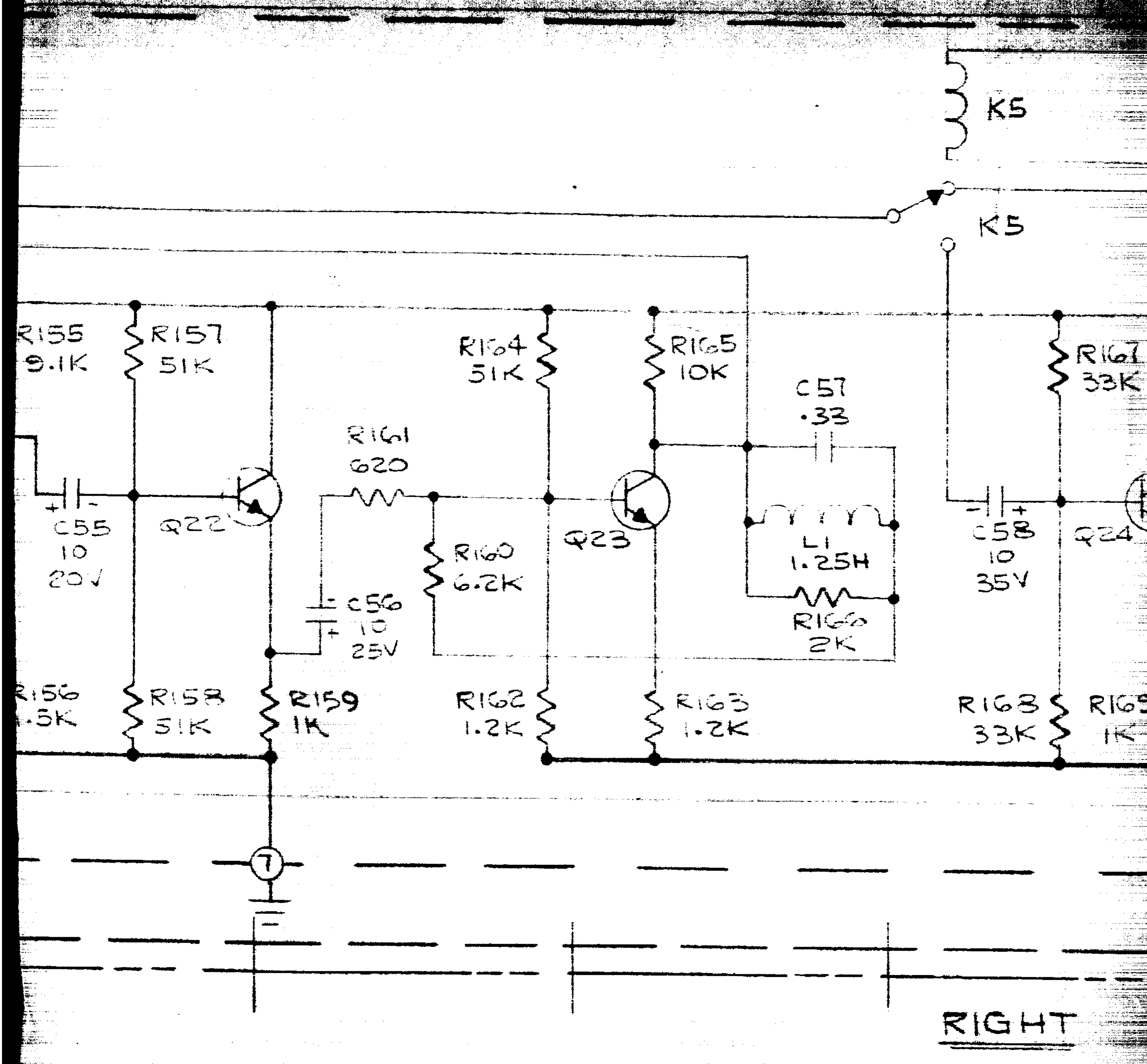
3



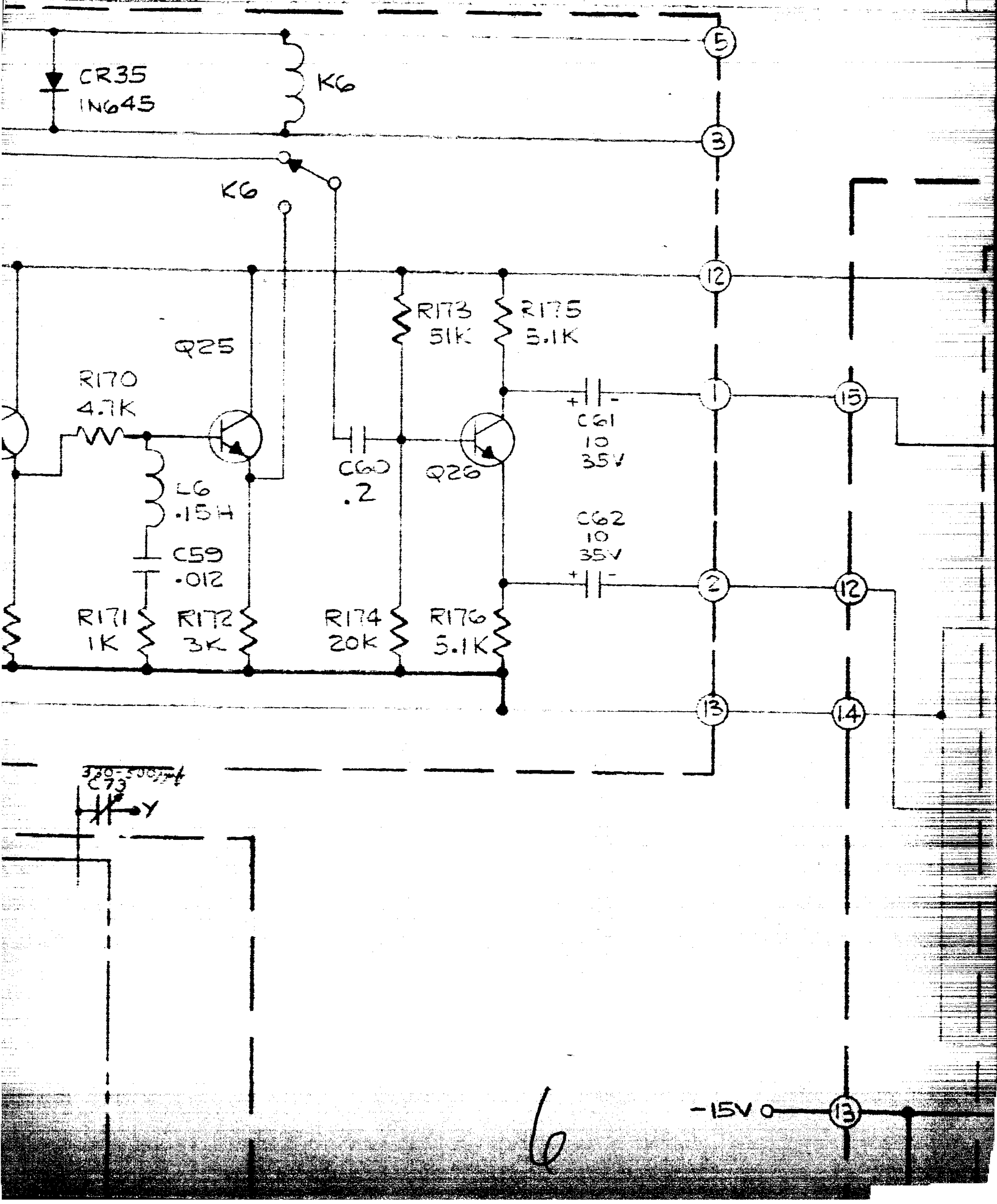
R128
8.2K
C43
10
35V
R129
330K
R130
150K
Q15
R131
8.2K
R132
5.6K
C44
10
35V
C45
10
35V
R133
330K
R134
150K
Q16
R135
8.2K
R136
5.6K
C46
10
35V
C47
10
35V
R137
330K
R138
150K
Q17
R139
8.2K
R140
5.6K
C48
10
35V
C42
10
35V
11
10
9
8
L2
2.5h
R199
39K
C68
.1
L3
2.5h
R200
39K
C69
.1
L4
2.5h
R201
39K
C70
.1
T4
T5
T6
CR30
FA2011
R202
680
CR31
FA2011
R204
680
CR32
FA2011
R206
680



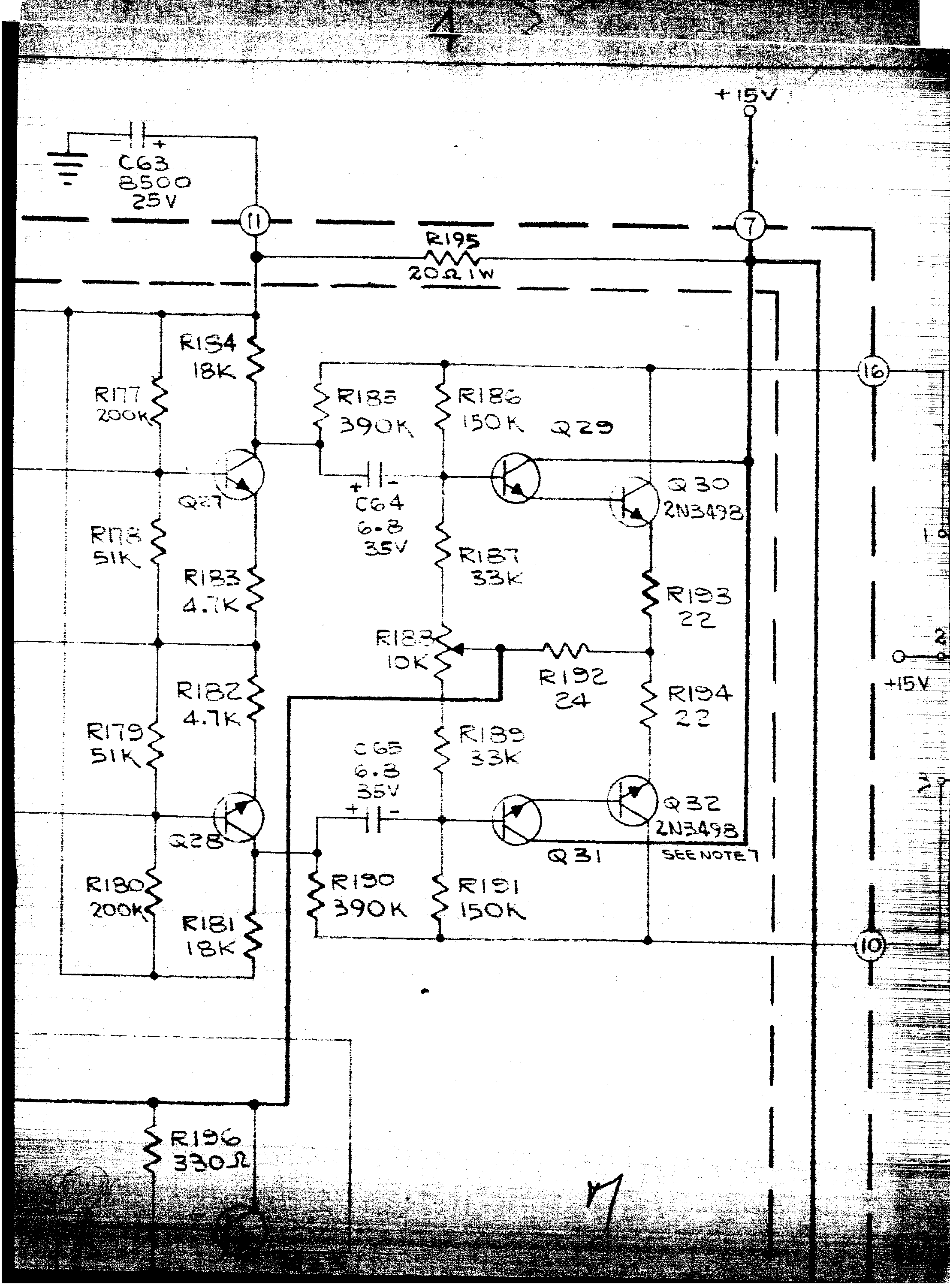
R141
33K
R145
51K
R148
9.1K
R149
51K
R152
39K
C51
.1
C54
.1
C50
10
35V
Q18
Q19
Q20
Q21
C52
10
35V
R153
620
R144
620
C53
10
20V
R142
51K
R143
1K
R146
4.7K
R147
1.2K
R150
51K
R151
1K
R154
4.7K
13
LEFT
L2 THRU L5 &
T4 THRU T7
SEE NOTE # 5
C400332
CR33
FA2011
R208
680
CR33A
R209
4


K5
K5
R155
9.1K
R157
51K
R164
51K
R165
10K
R167
33K
C57
.33
R161
620
C55
10
20V
Q22
Q23
R160
6.2K
L1
1.25H
C58
10
35V
Q24
C56
10
25V
R166
2K
R156
R158
51K
R159
1K
R162
1.2K
R163
1.2K
R168
33K
1K
7
RIGHT

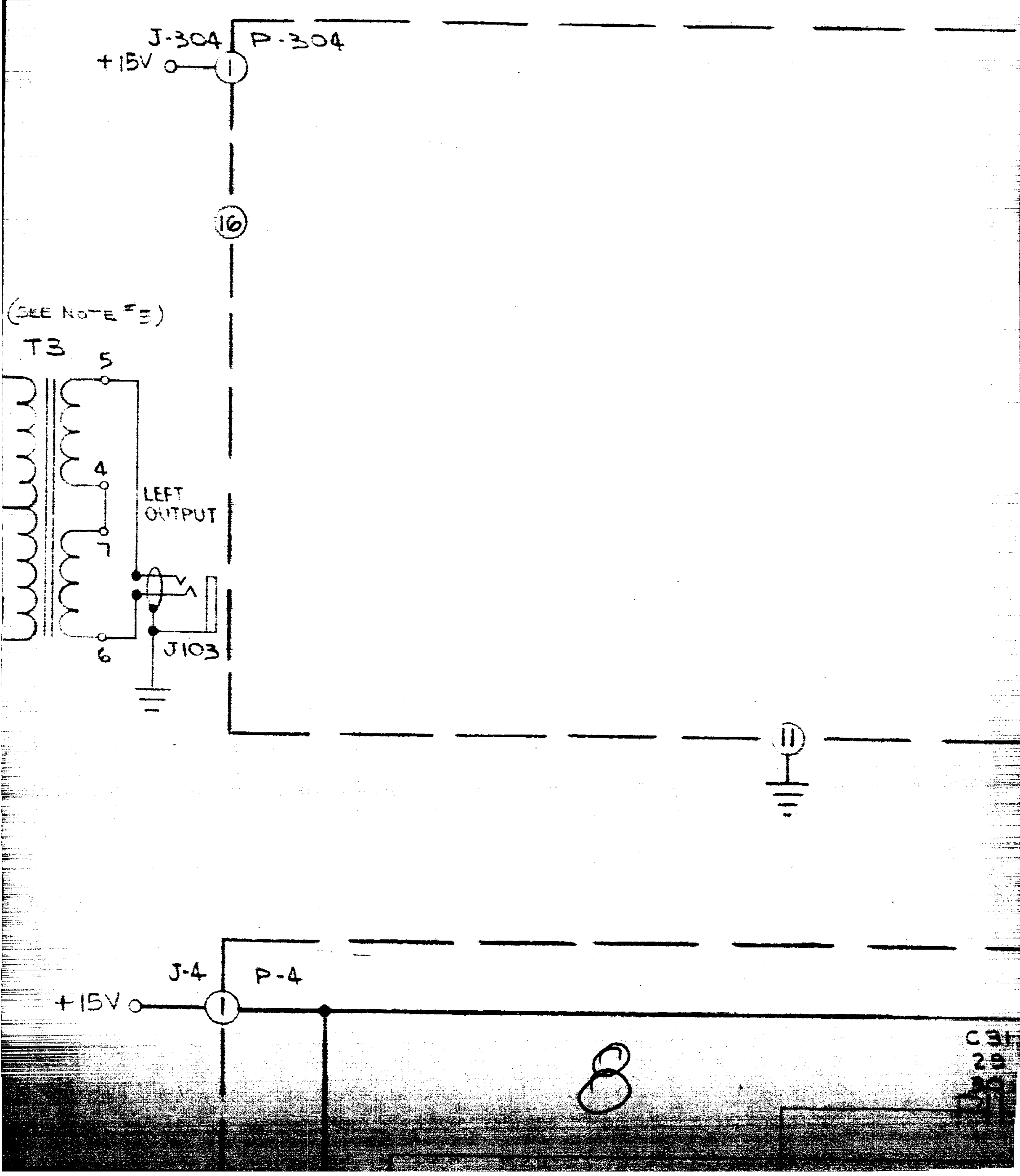
5


CR35
1N645
K6
K6
Q25
R170
4.7K
L6
.15H
C59
.012
R171
1K
R172
3K
R173
51K
R175
5.1K
C60
.2
Q26
R174
20K
R176
5.1K
C61
10
35V
C62
10
35V
C73
-15V
5
3
12
1
2
13
15
12
14
13

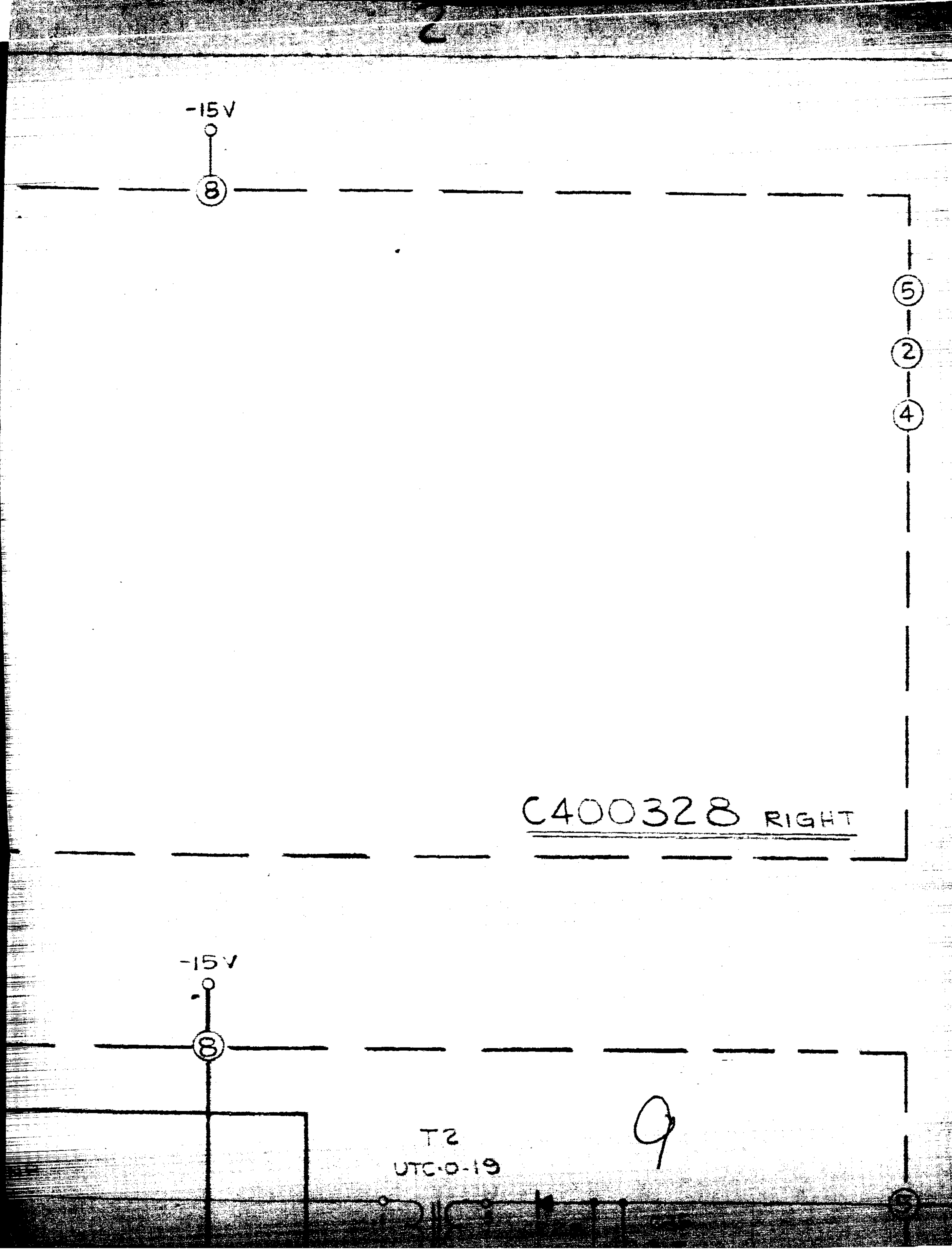
6



+15V
C63
8500
25V
11
7
R195
20Ω 1W
R184
18K
R177
200K
R185
390K
R186
150K
Q29
Q27
C64
6.8
35V
Q30
2N3498
R178
51K
R183
4.7K
R187
33K
R193
22
R188
10K
R192
24
R194
22
+15V
R182
4.7K
R179
51K
R189
33K
C65
6.8
35V
Q28
Q32
2N3498
Q31
SEE NOTE 7
R190
390K
R191
150K
R180
200K
R181
18K
16
10
R196
330Ω



J-304
P-304
+15V
1
16
(SEE NOTE #3)
T3
5
4
7
6
LEFT OUTPUT
J103
11
J-4
P-4
+15V
1
8

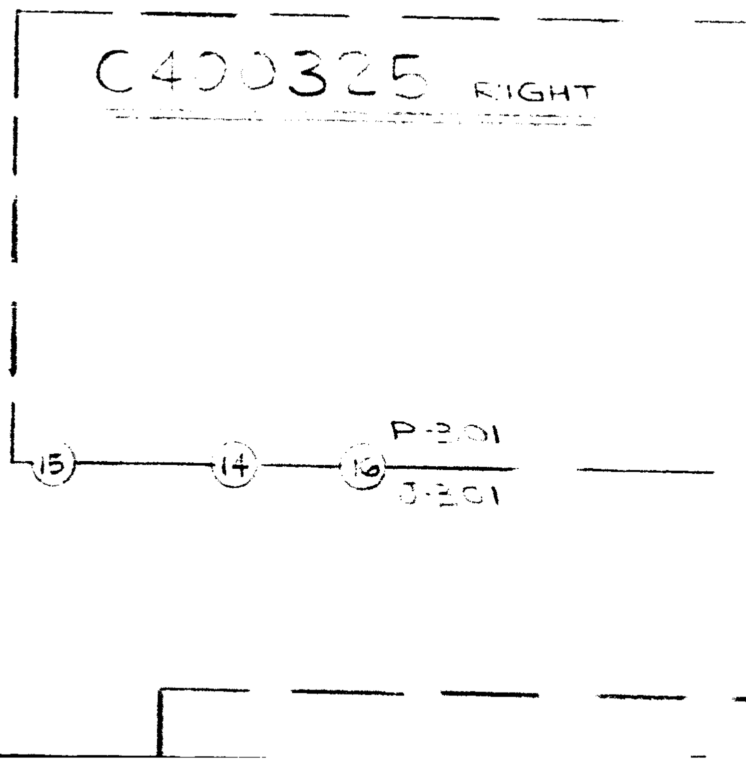

2
-15V
8
5
2
4
C400328 RIGHT
-15V
8
9
T2
UTC-O-19
5

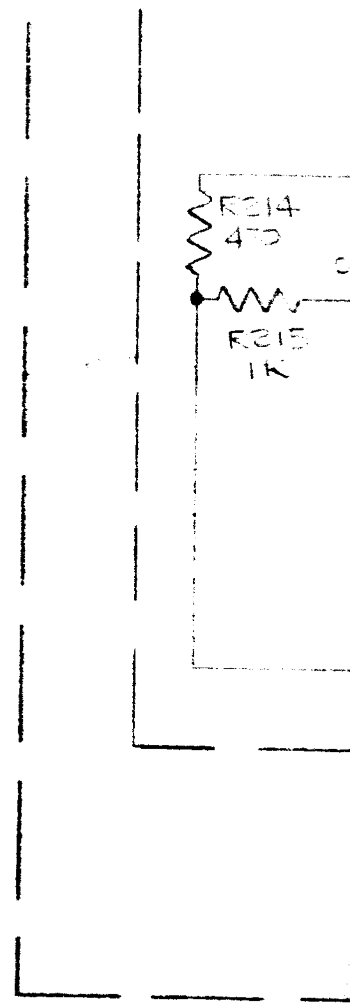
REVISIONS			
SYM	DESCRIPTION	DATE	APPROVAL
A	SEE ECN # 1191	7-28-66	

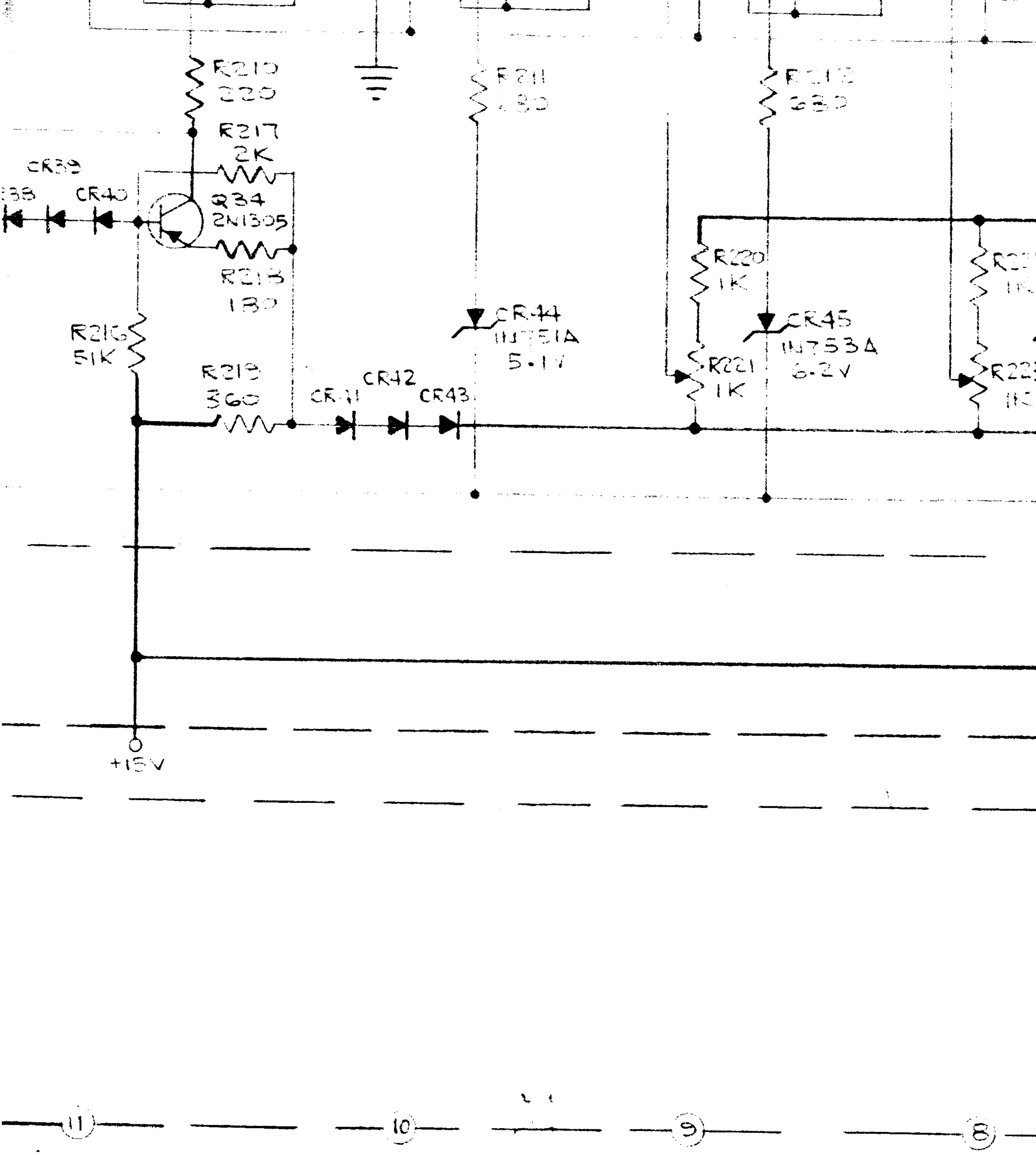
H

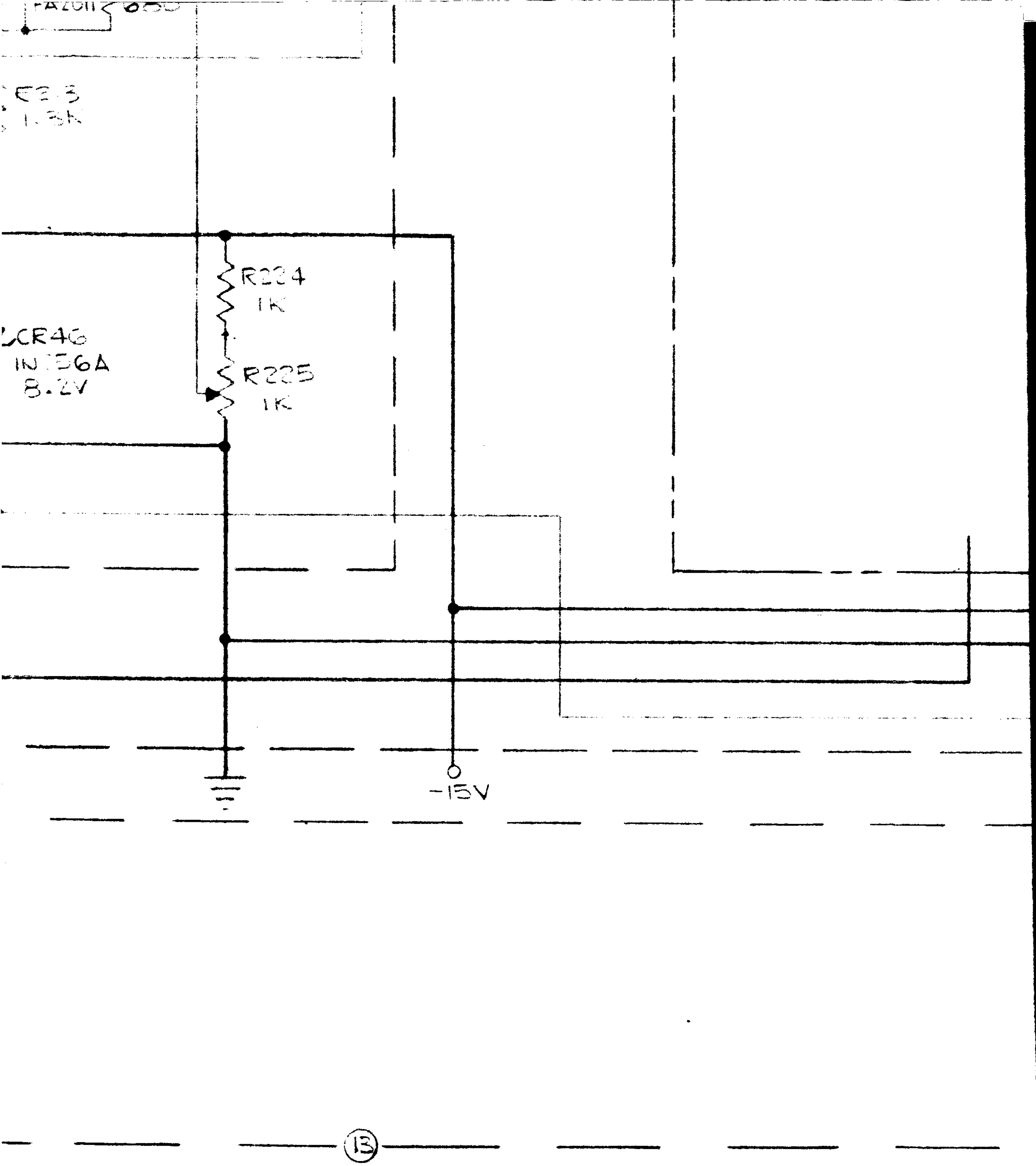
G

10

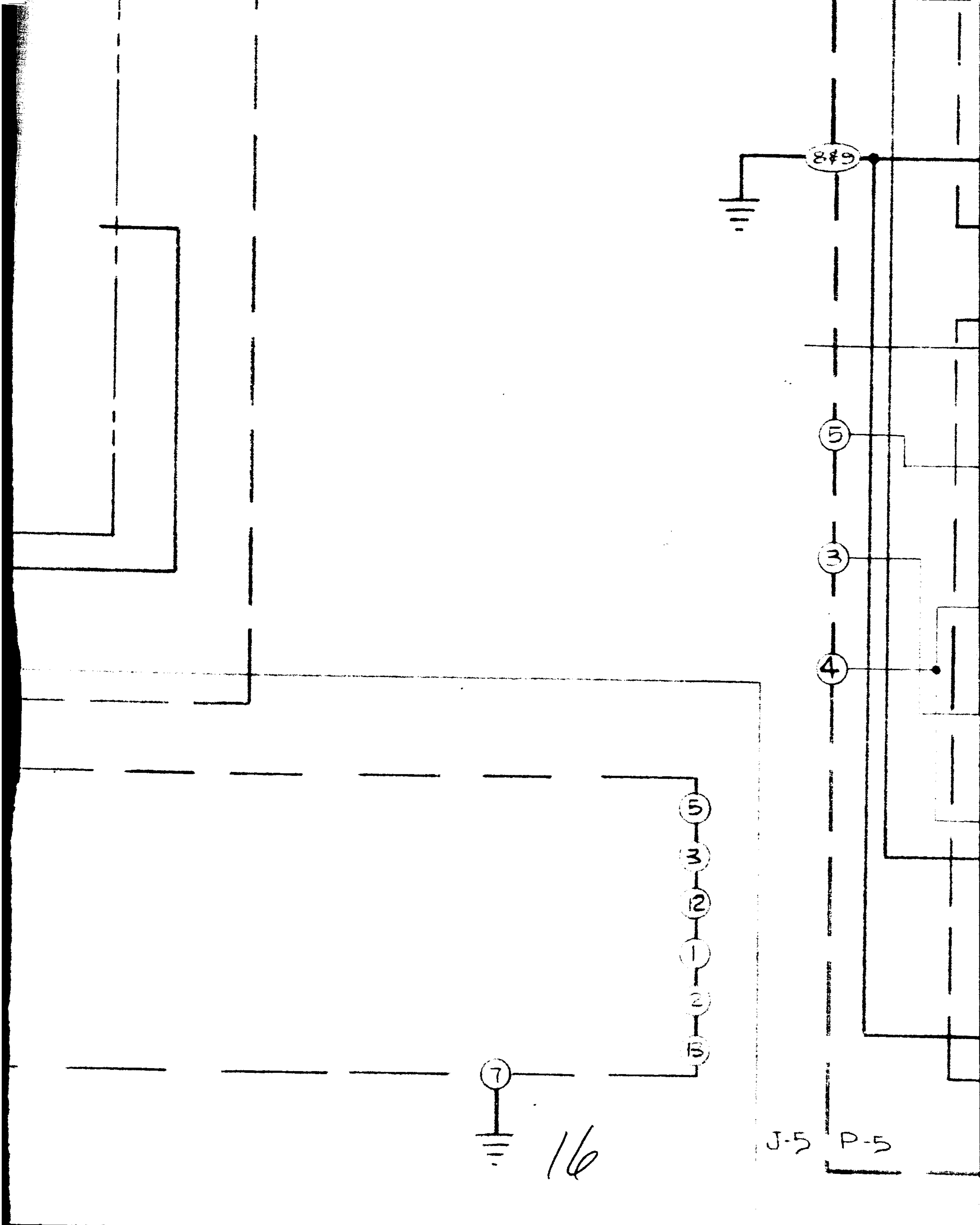

C400325 RIGHT
15
14
16
P-301
J-301


R214
470
R215
1K

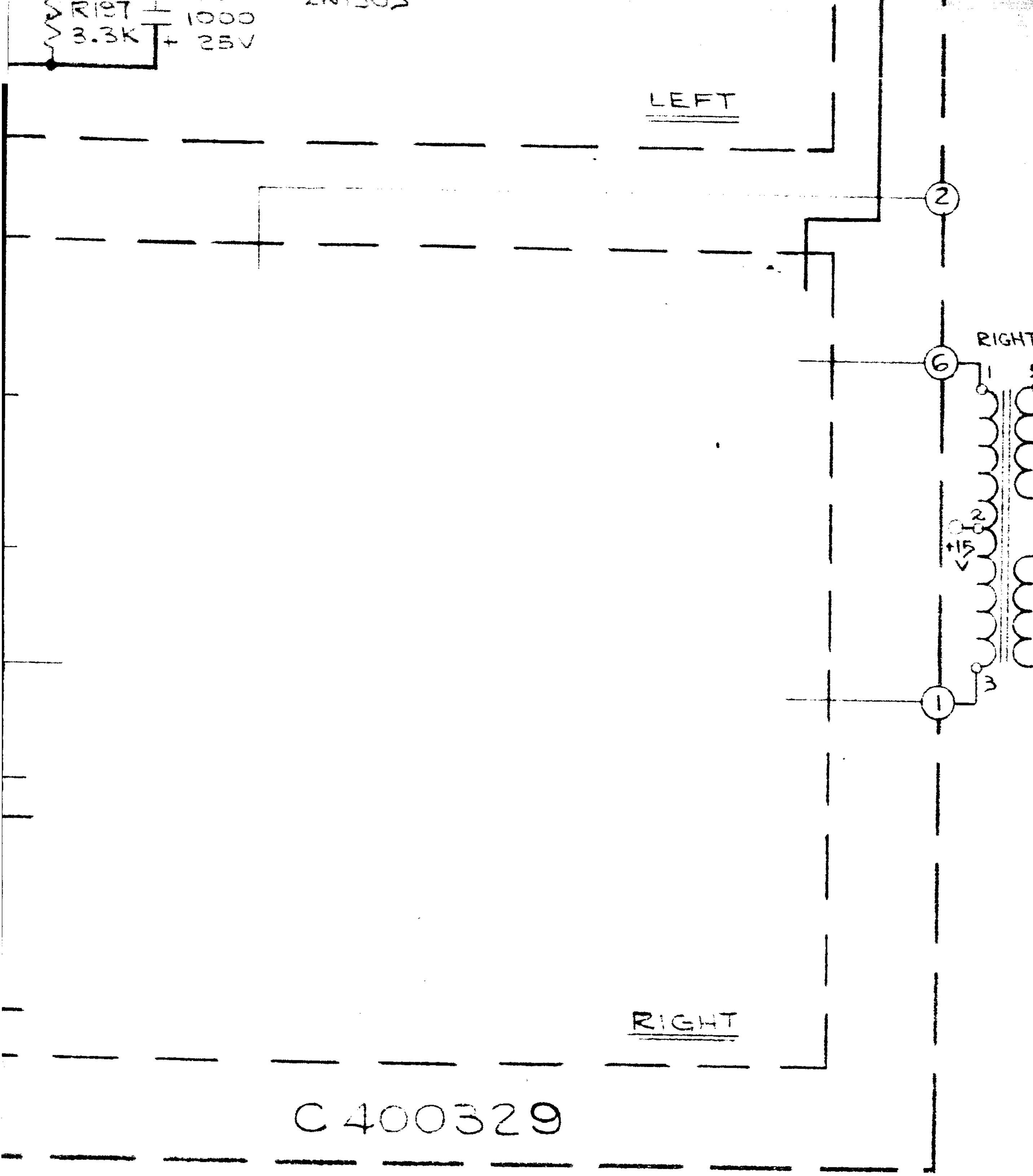

R210
220
R211
R212
680
R217
2K
CR39
CR40
Q34
2N1305
R218
180
R220
1K
CR44
1N751A
5.1V
CR45
1N753A
6.2V
R216
51K
R219
360
CR41
CR42
CR43
R221
1K
+15V
11
10
9
8

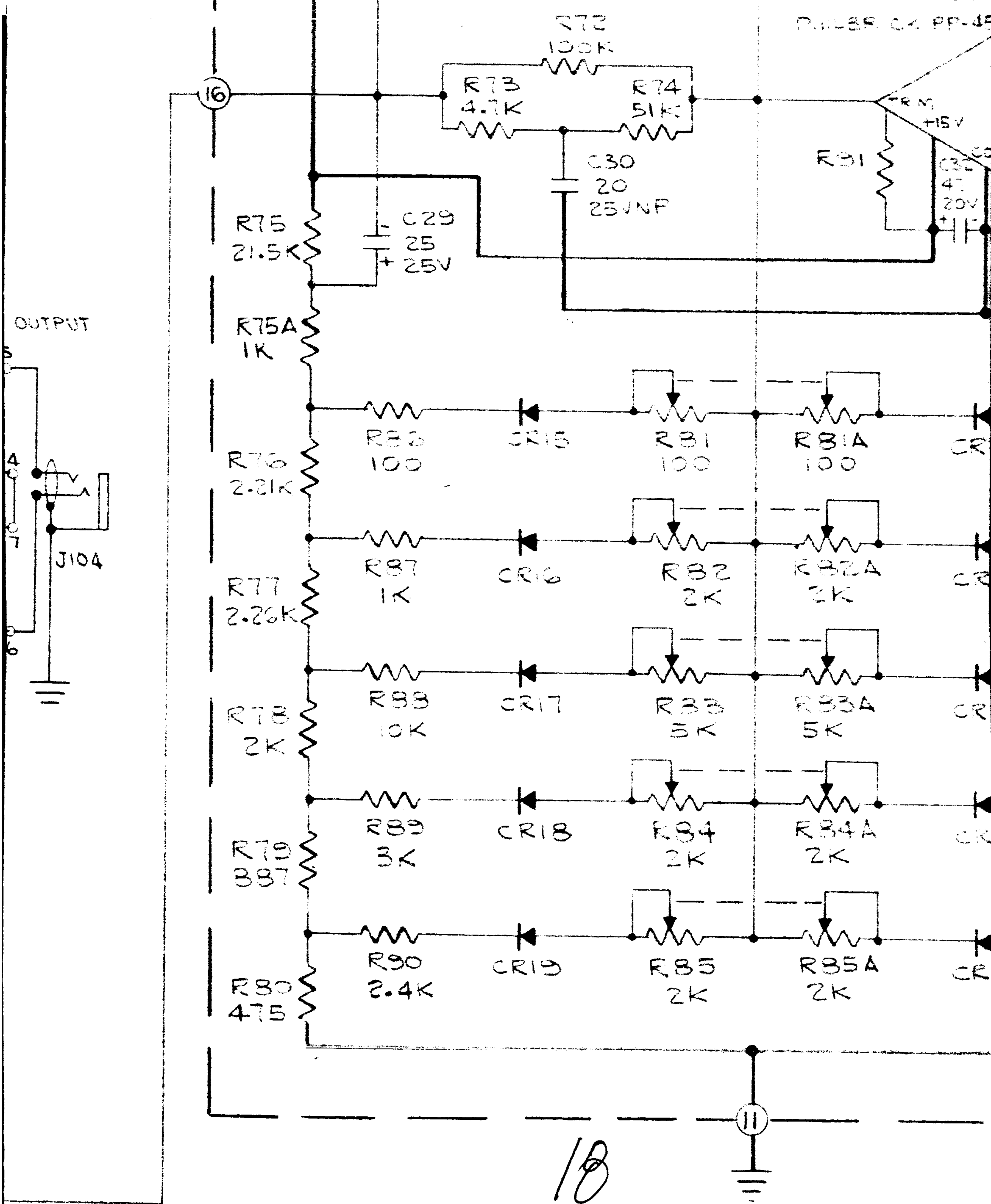


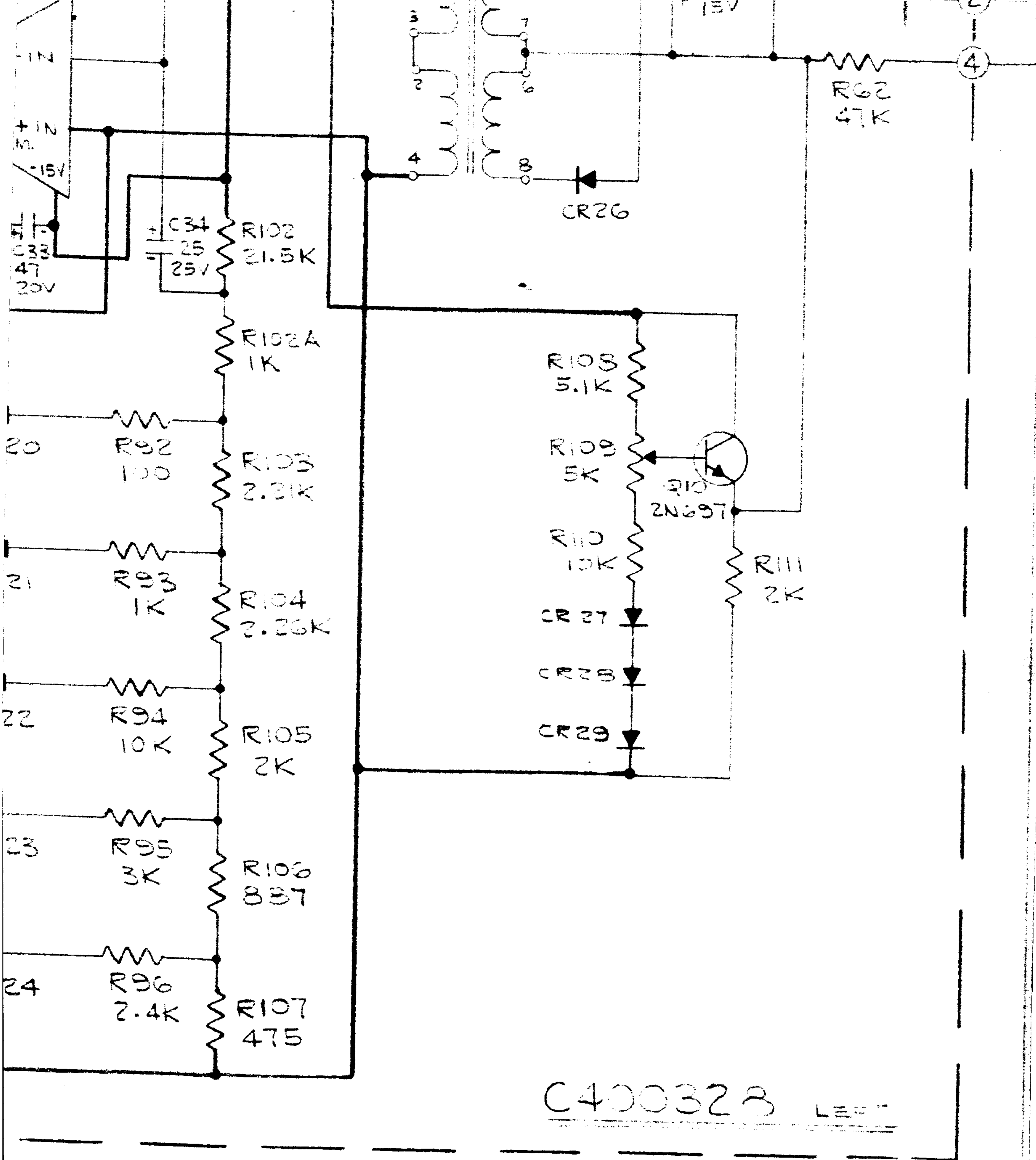
14



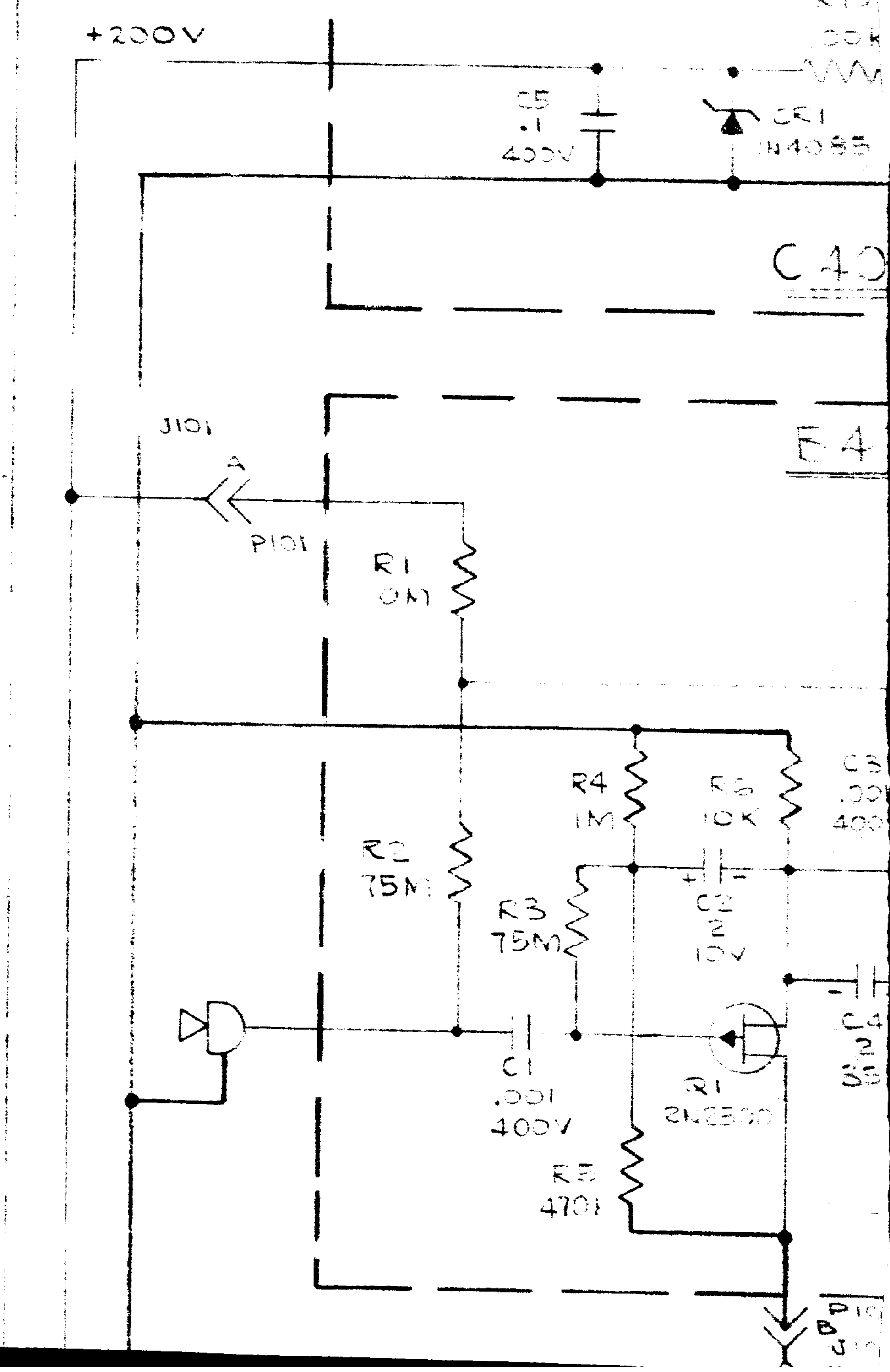
16


R197
3.3K
1000
+ 25V
LEFT
2
6
RIGHT
1
2
+15 V
3
1
RIGHT
C 400329

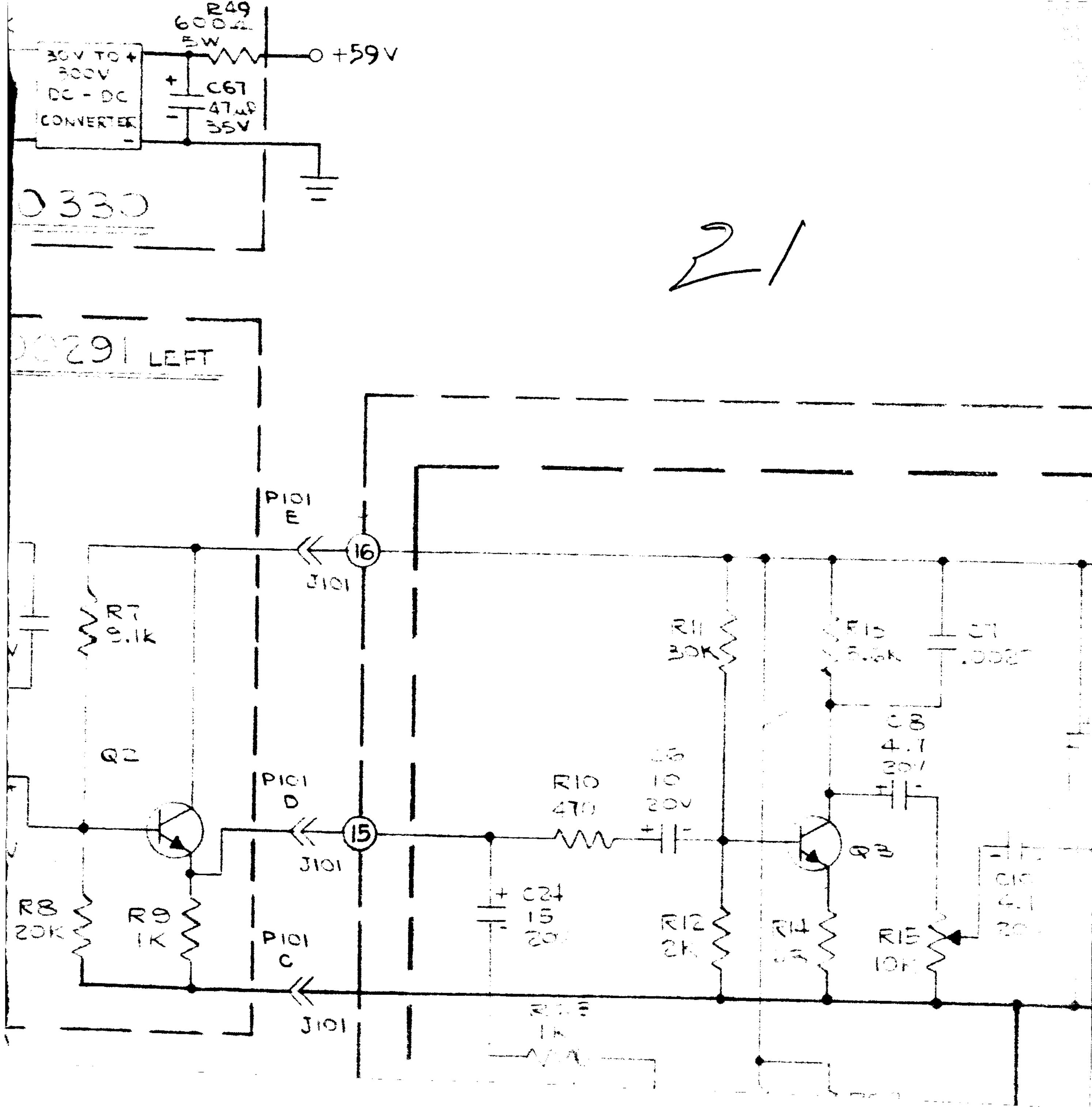

R72
100K
R73
4.7K
R74
51K
TRIM
+15V
R91
C30
20
25VNP
C32
47
20V
16
R75
21.5K
C29
25
25V
R75A
1K
OUTPUT
J104
R76
2.21K
R77
2.26K
R78
2K
R79
387
R80
475
R86
100
CR15
R81
100
R81A
100
R87
1K
CR16
R82
2K
R82A
2K
R88
10K
CR17
R83
5K
R83A
5K
R89
3K
CR18
R84
2K
R84A
2K
R90
2.4K
CR19
R85
2K
R85A
2K
11

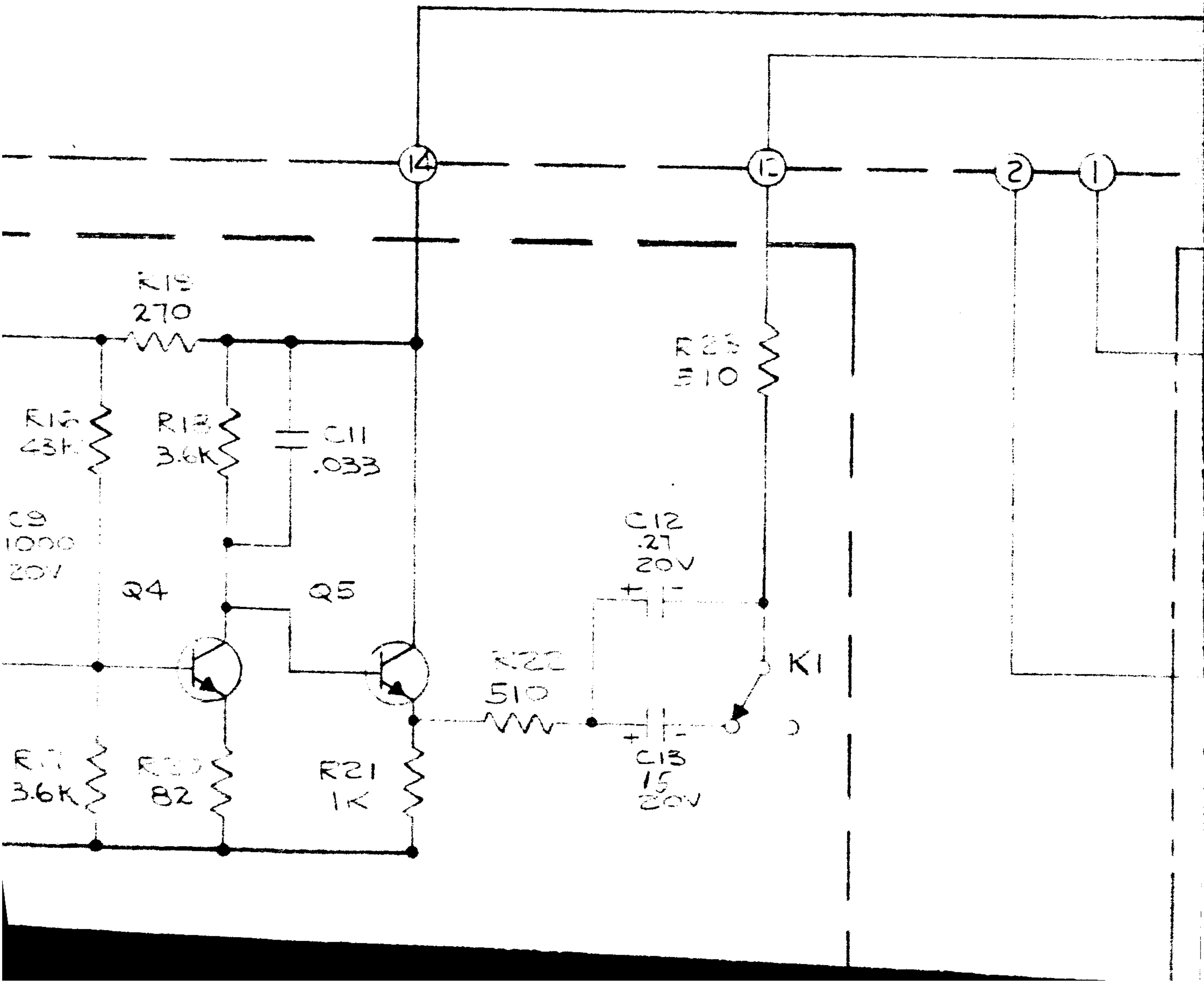


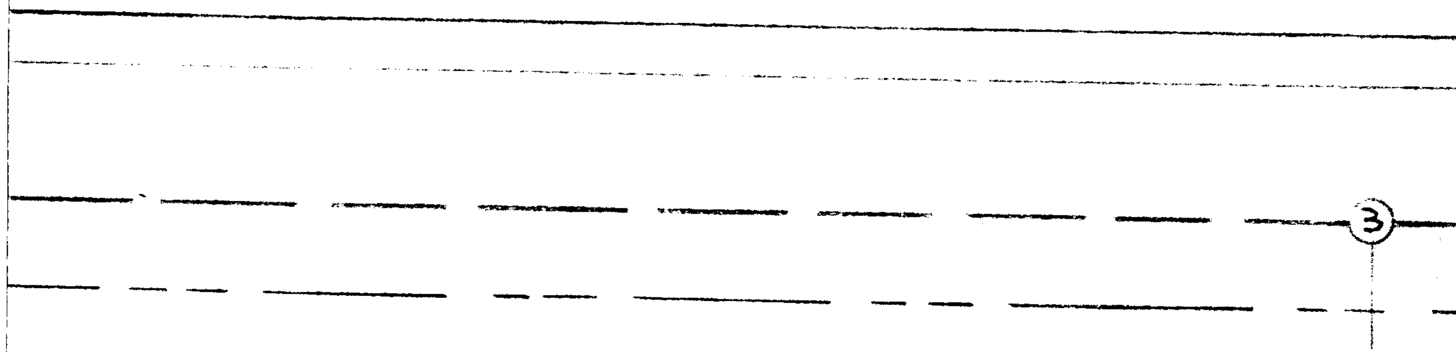
-IN
+IN
-15V
+15V
C33
47
25V
C34
25
25V
R102
21.5K
R102A
1K
R92
100
R103
2.21K
R93
1K
R104
2.26K
R94
10K
R105
2K
R95
3K
R106
837
R96
2.4K
R107
475
CR26
R62
47K
4
R108
5.1K
R109
5K
R110
10K
Q10
2N697
R111
2K
CR27
CR28
CR29
C400328

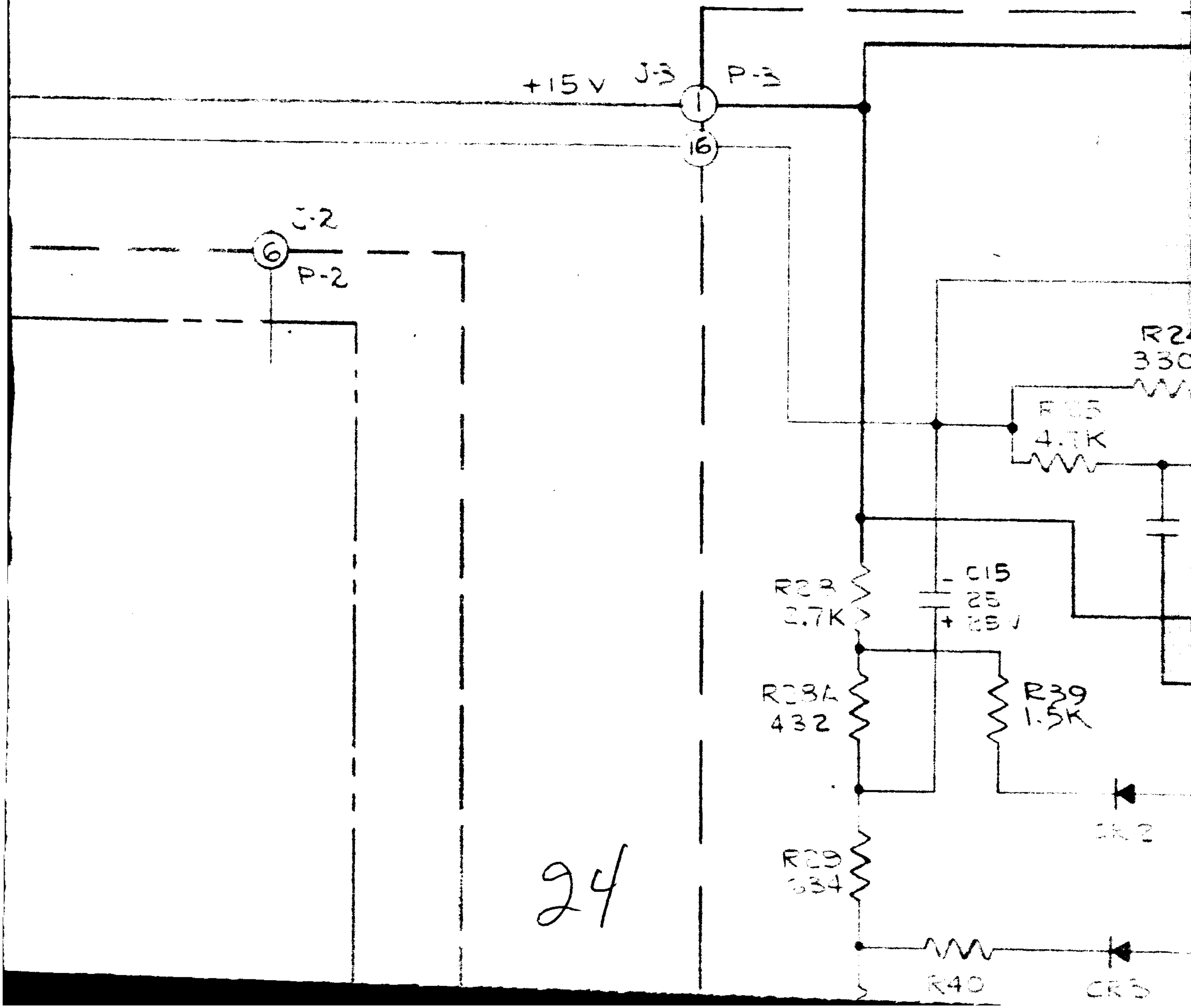

+200V
C5
.1
400V
CR1
J101
A
P101
R1
R2
75M
R3
75M
R4
1M
R6
10K
C2
2
10V
C1
.001
400V
Q1
R5
B

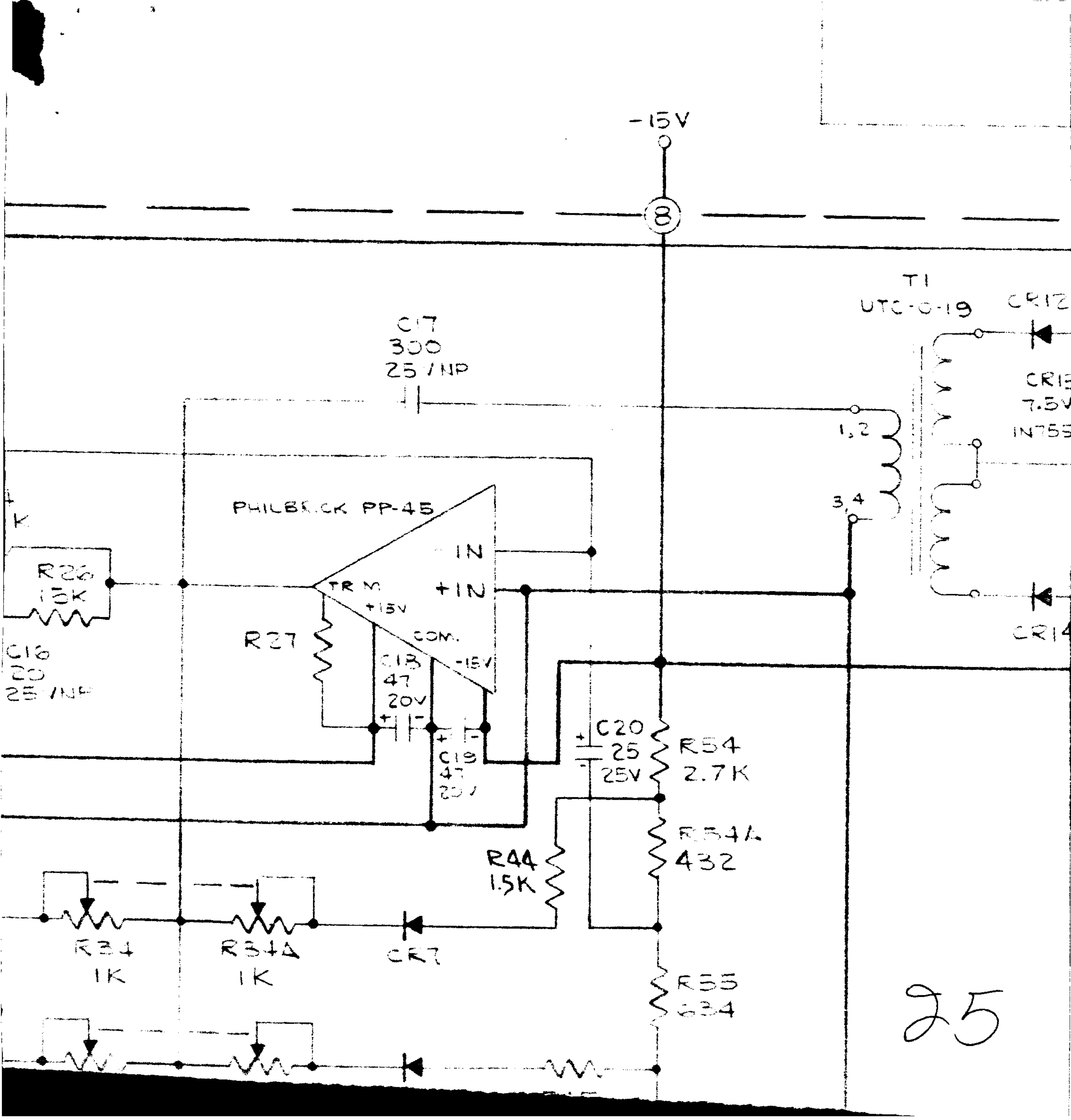
20


30V TO 300V DC - DC CONVERTER
R49
600Ω
5W
+59V
C67
47μF
35V
0330
21
0291 LEFT
P101
E
16
J101
R7
9.1k
R11
30K
C7
Q2
P101
D
15
J101
R10
470
C8
4.7
Q3
R8
20K
R9
1K
P101
C
C24
15
R12
2K
R14
R15
10K
J101
1K

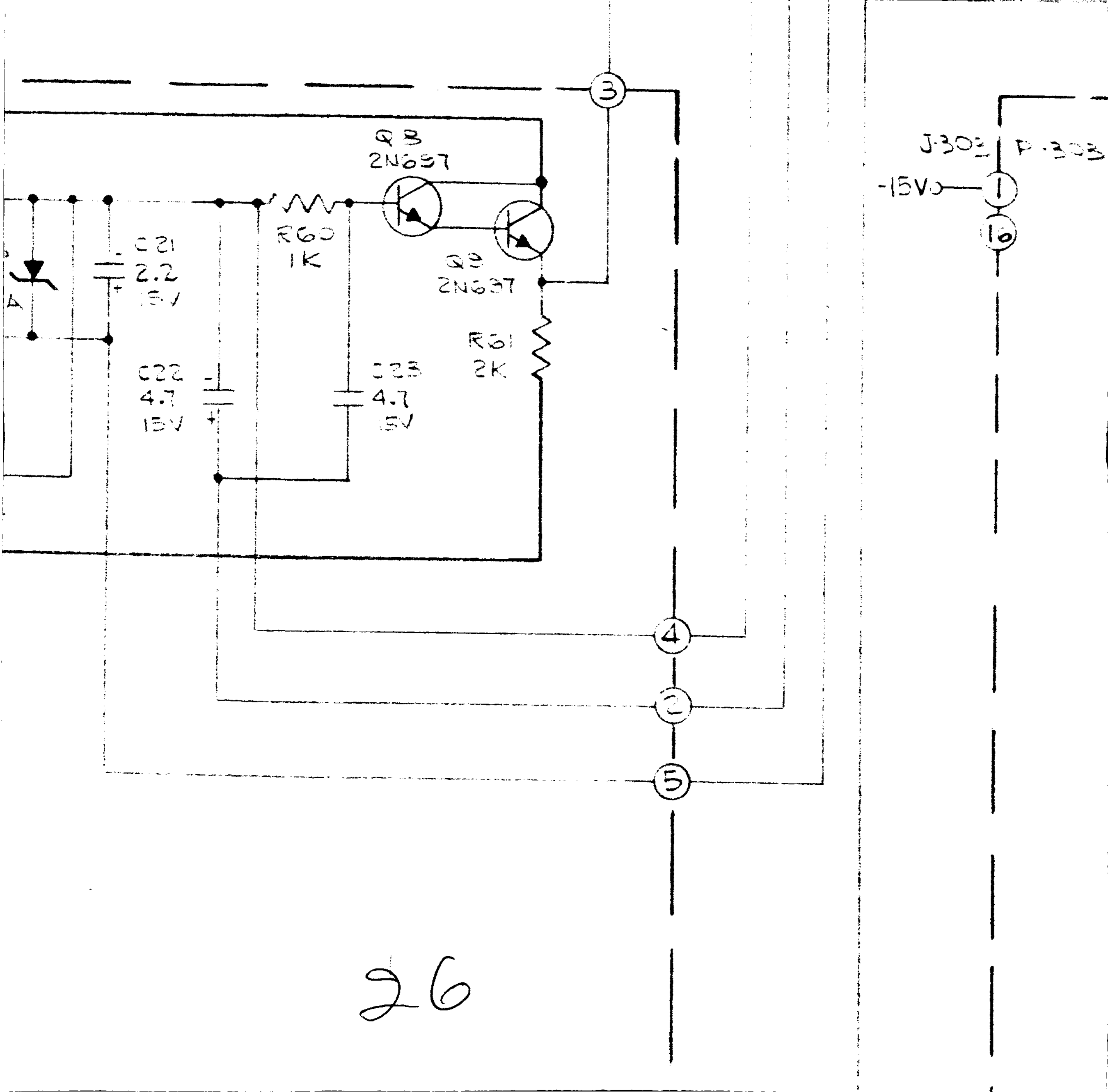

R19
270
R16
43K
R18
3.6K
C11
.033
C9
1000
20V
Q4
Q5
R23
510
C12
.27
20V
R22
510
K1
C13
15
20V
R17
3.6K
R20
82
R21
1K
14
2
1

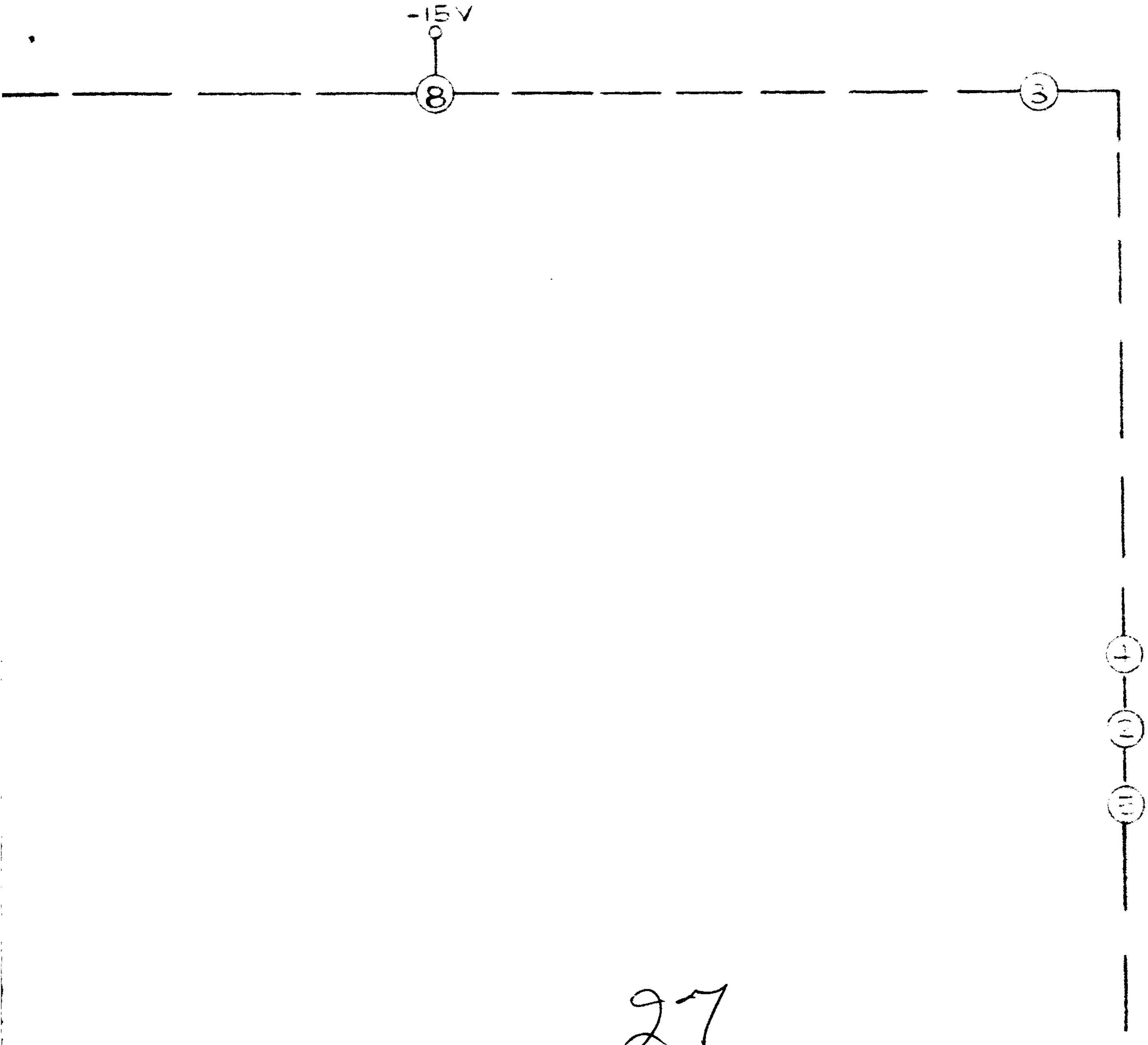

3


+15 V
J-3
P-3
1
16
6
P-2
R39
1.5K
R28A
432
C15
CR3
R40
24

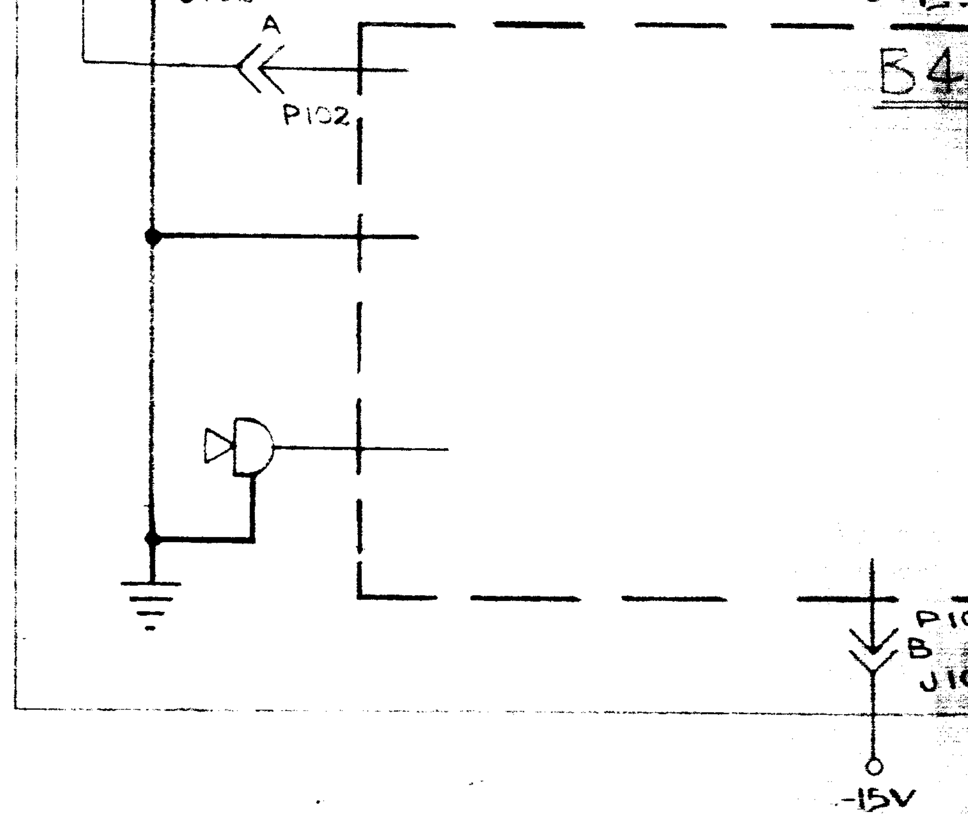


-15V
8
T1
UTC-O-19
CR12
CR13
7.5V
IN755
CR14
C17
300
25V/NP
1,2
3,4
PHILBRICK PP-45
-IN
+IN
TRIM
+15V
COM.
-15V
R26
15K
C16
20
25V/NP
R27
C18
47
20V
C19
47
20V
C20
25
25V
R54
2.7K
R54A
432
R44
1.5K
R34
1K
R34A
1K
CR7
R55
634
25


Q8
2N697
Q9
2N697
R60
1K
R61
2K
C21
2.2
15V
C22
4.7
15V
C23
4.7
15V
J302
P303
-15V
1
16
3
4
2
5


-15 V
8
3

B

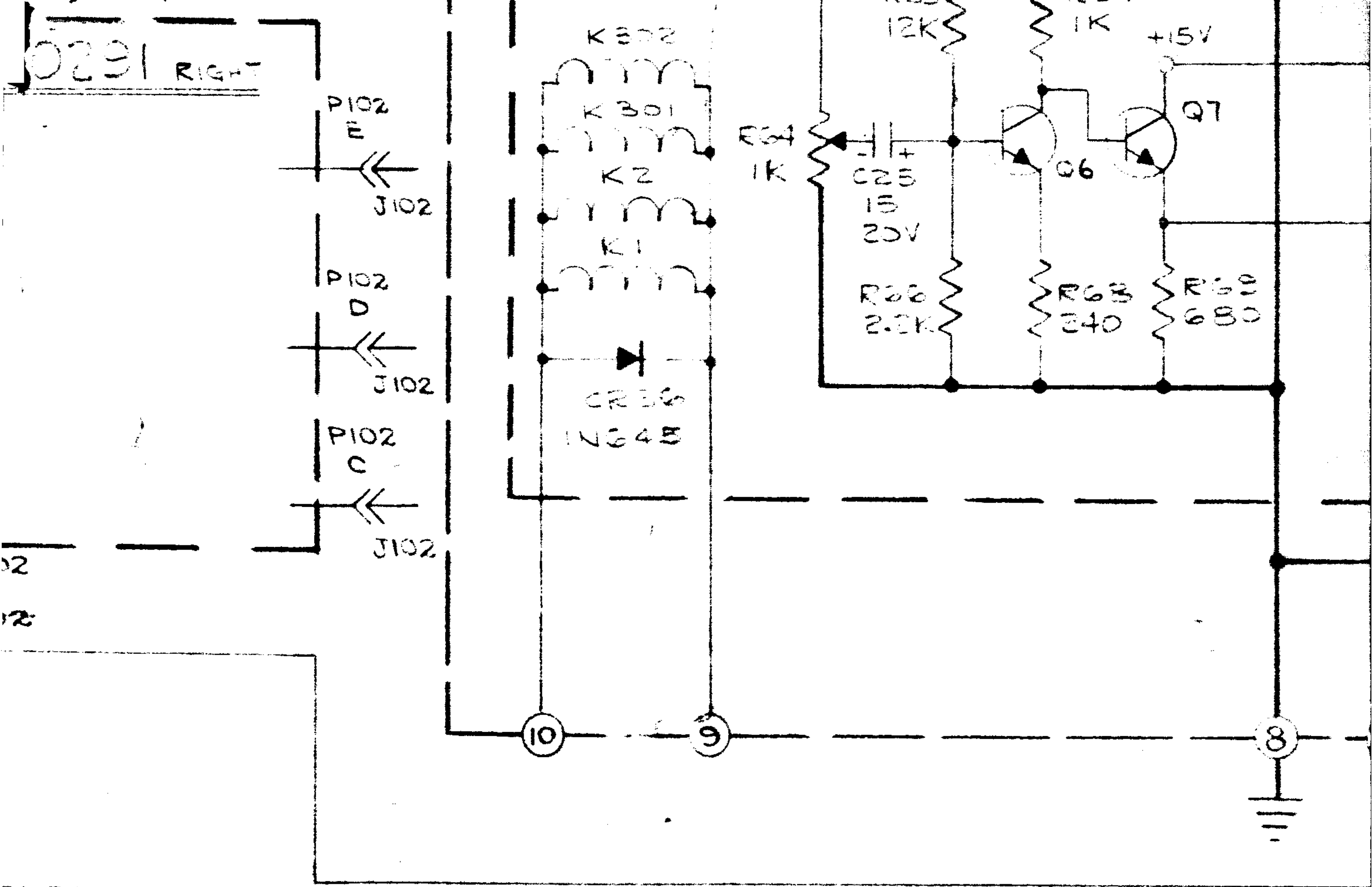


29

A

NOTES: UNLESS OTHERWISE SPECIFIED

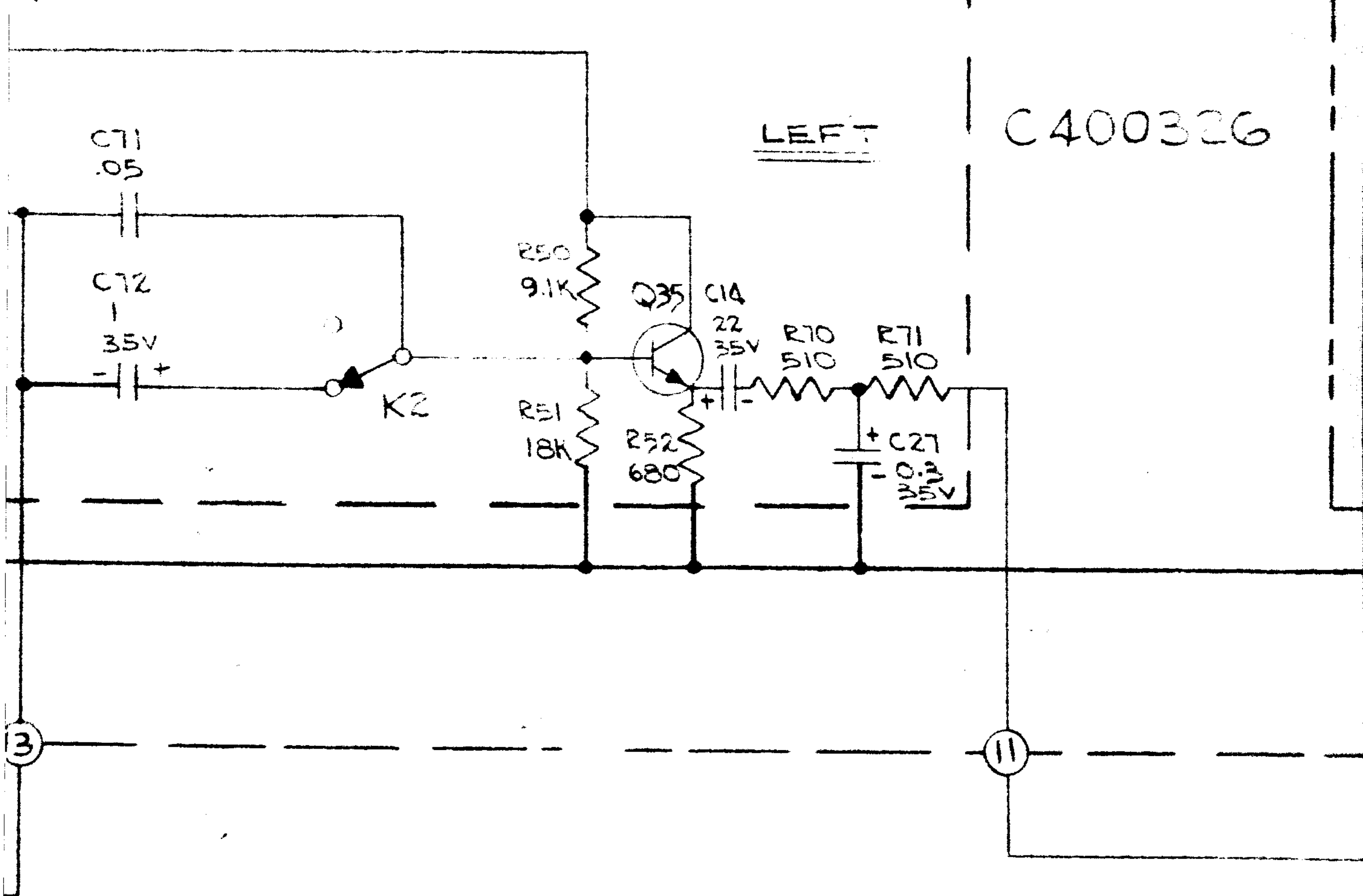
1. RESISTOR VALUES IN OHMS, UNLESS FOLLOWED BY K=1,000 OHMS OR MEG=1,000,000 OHMS. POWER RATING IS 1/4 WATT ±5%.
2. CAPACITORS ARE IN MICROFARADS UNLESS FOLLOWER BY μμf = MICRO-MICRO
3. DIODES NOT MARKED ARE IN456A
4. TRANISTORS NOT MARKED ARE 2N3391 A.
5. L2, L3, L4, L5 (L302, L303, L304, L305) AND T3, T4, T5, T6, T7 (T303, T304, T305, T306, T307) A
6. COMPONENTS DESIGNATIONS ARE : 0-299 LEFT CHANNEL, 300-599
   700-799 PWR. SUPPLIES & CONTROL C
   900-999 SPEECH CHANNEL.
7. TRANSISTOR Q30 & Q32 REQUIRE HEAT SINK, MFG WAKEFIELD # NF209.



FARADS

RE MOUNTED ON DWG # C400333
RIGHT CHANNEL,
NTS, 800-399 REMOTE CONTROL UNIT,

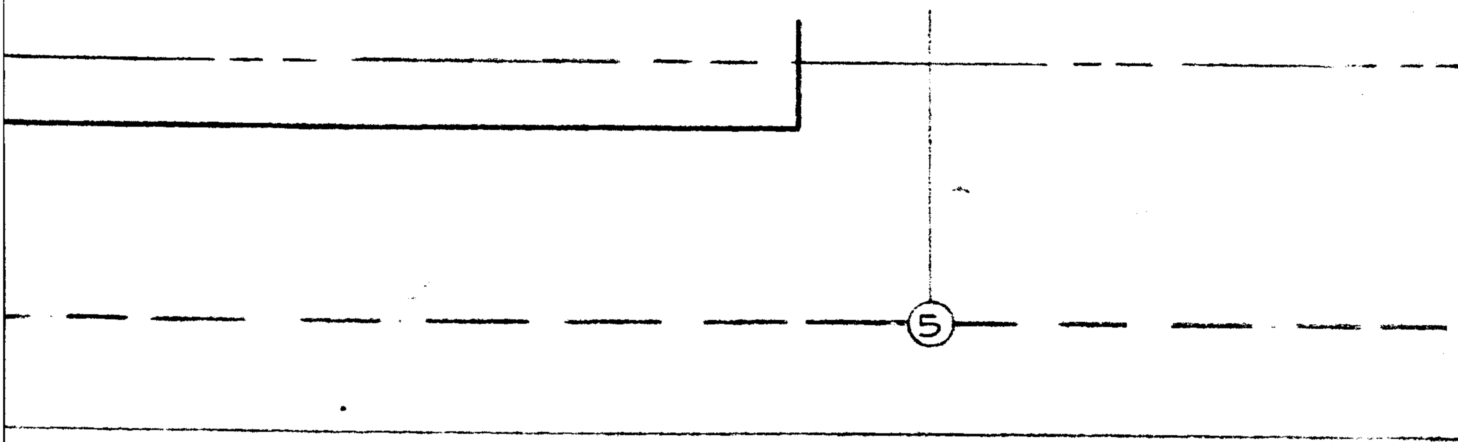
30

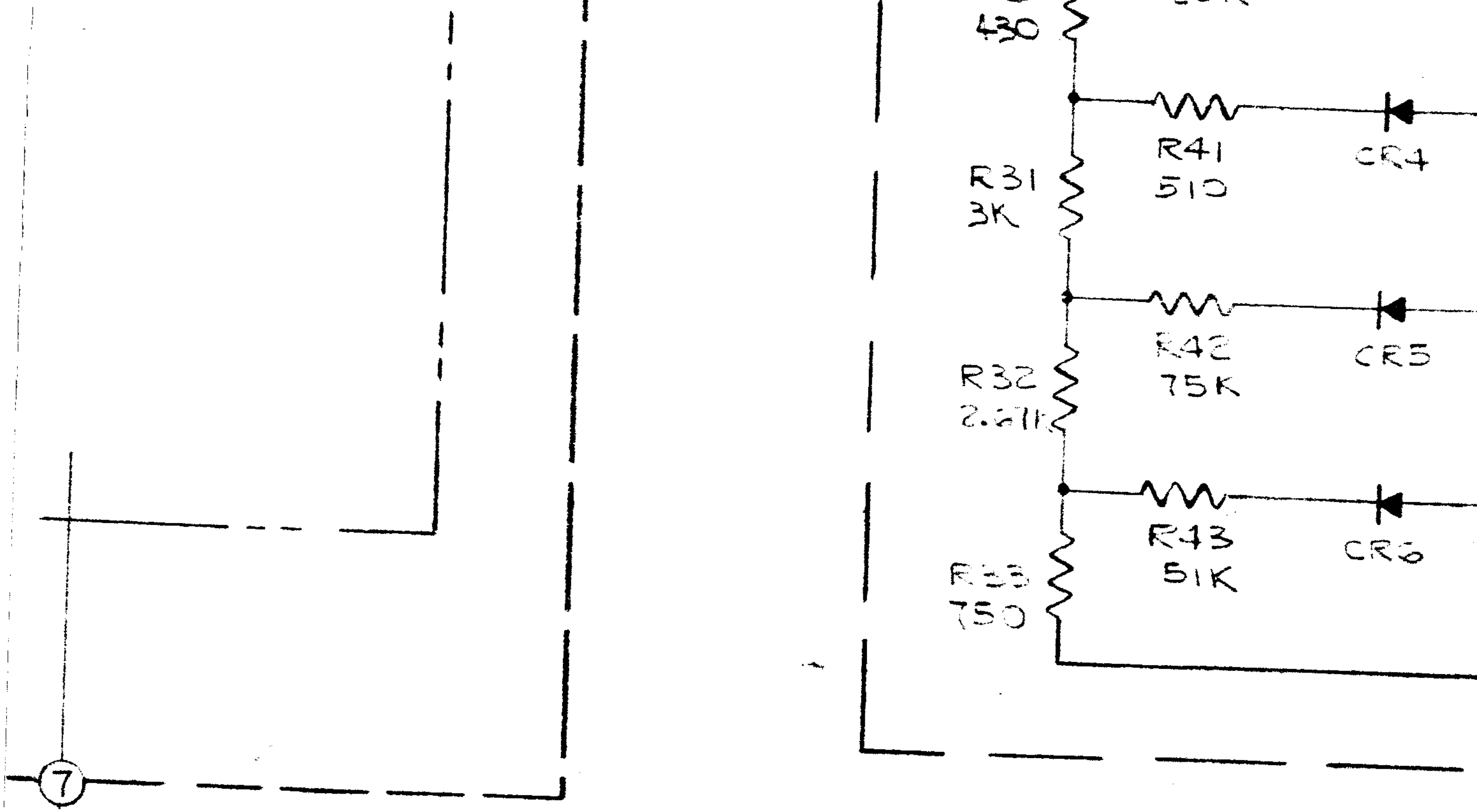


LEFT
C400326
C71
.05
C72
1
35V
K2
R50
9.1K
R51
18K
Q35
C14
22
35V
R52
680
R70
510
R71
510
C27
0.2
35V
13
11

31

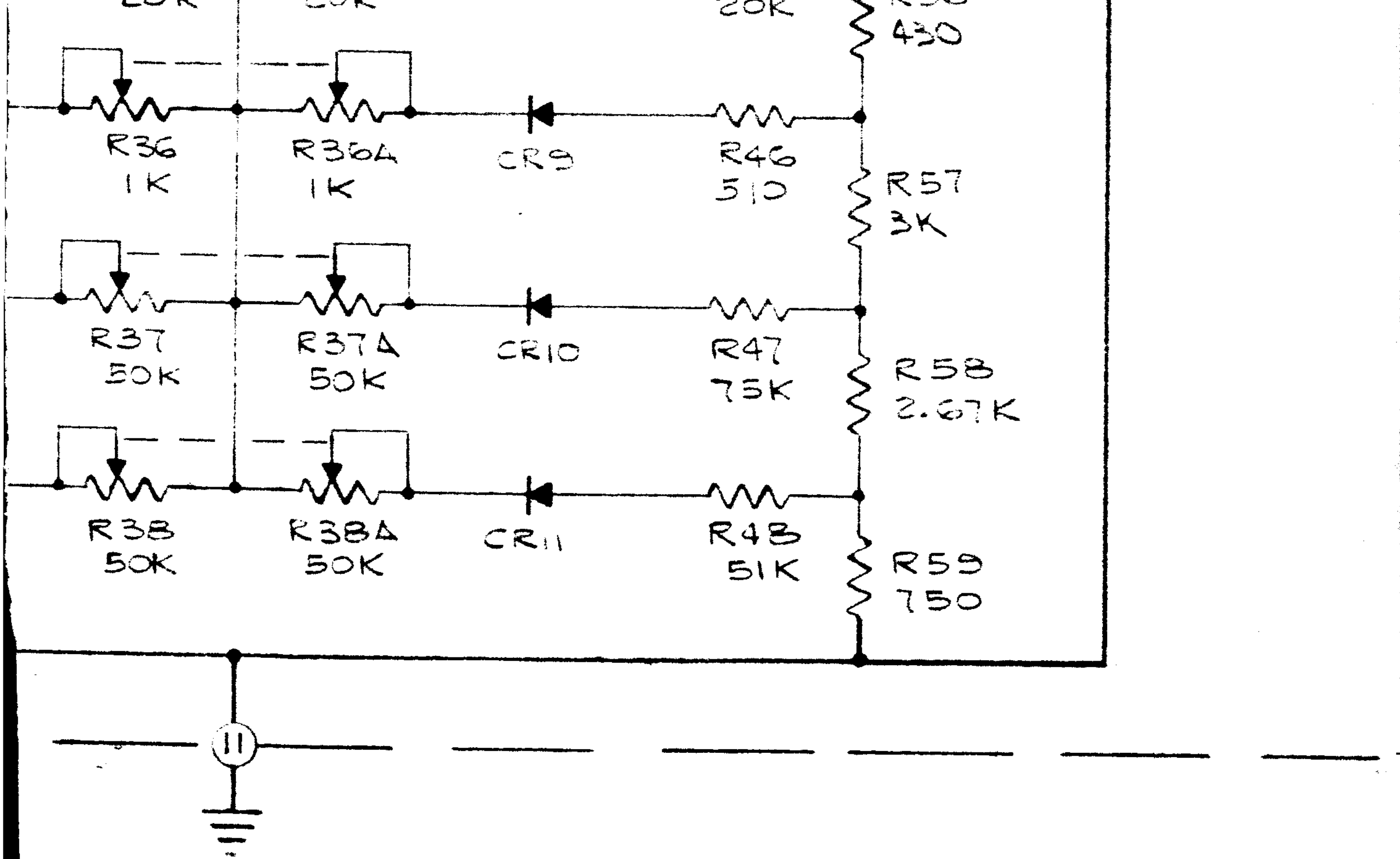
RIGHT





33

6


430
R36
1K
R36A
1K
CR9
R46
510
R57
3K
R37
50K
R37A
50K
CR10
R47
75K
R58
2.67K
R38
50K
R38A
50K
CR11
R48
51K
R59
750
11

34

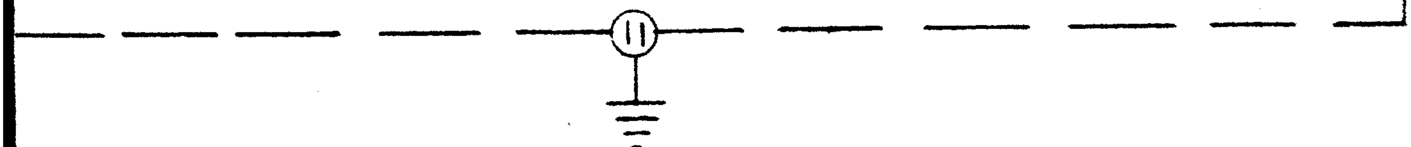
5

C400327 LEFT

365

4

C400327 RIGHT



~~37~~ 36

3

B

NOMENCLATURE OR DESCRIPTION	MATERIAL OR SPECIFICATION		SYM

LIST OF MATERIALS

S9-4414

	DATE
	1-3-66
...ione	1-5-66
	1-6-66
	1-6-66

CBS LABORATORIES Stamford, Conn.
A Division of Columbia Broadcasting System, Inc.

AURAL SIMULATOR
SCHEMATIC
(ELECTRONIC DUMMY)

SIZE	CODE IDENT NO.	
J	16996	400363

SCALE None SHEET OF

A

~~38~~ 38

-5	-4	-3	-2	-1	ITEM	PART OR IDENTIFYING NO.
QTY REQD						

	E400466	1037-001
DASH NO.	NEXT ASSY	USED ON
	APPLICATION	

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON
FRACTIONS DECIMALS ANGLES

MATERIAL

FINISH

CONTRACT NO. NA

DRAWN

CHECKED

ENGINEER

RELIABILITY

REVIEW

APPROVAL (PROJECT

APPROVAL (GOVT)

37 2